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Mats Myrberg

Towards an Ergonomic Theory of Text Design and Composition

1978

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Mats Myrberg

Towards an Ergonomic Theory of Text Design and Composition

Doctoral Dissertation
to be publicly examined at Upsala University, lecture room VIII, on May 27, 1978, at 10 a.m. for the Degree of Doctor of Philosophy (According to Royal proclamation No 327, 1969).

Abstract: The dissertation describes three consecutive approaches to problems in representing graphical information in talking books for the visually handicapped. Theories of human information processing are the common denominator for the three approaches. The first approach is concerned with methods of verbal description which might enhance the readers comprehension of a figure description. The second approach aims at ascertaining the effect of editing operations taking place before the actual recording of the talking book (primarily the effect of omitting graphical material). A third approach sets out from the hypothesis that graphical information is an aid in the reading process rather than a carrier of new information, not conveyed by the text. A model of the effects of design information on the mental load on the reader is put forward. The model has a bearing upon problems connected with the design of retrieval- and display systems in general. Possibilities to test and develop the model further are discussed, and some of the potential areas of application are exemplified.

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Institution: Department of Educational Research, Uppsala University, Sweden.
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The first thoughts directing my attention to the problems treated in this thesis appeared during my studies at the Department of Psychology in Umeå ten years ago. Problems concerning human information processing have since constituted the core of my research. My perspective on human information processing has changed a lot during the last ten years. Professor K-G Ahlström, who has been the scientific leader of most of my projects, has influenced my thinking to a great extent. My work together with Nils Trowald has also meant a lot, especially for the methodological aspects of carrying out the experiments I have made. Sven Amcoff and Lars-Göran Nilsson have often discussed my research problems with me, and made valuable comments. My wife Margareta has listened patiently during the long discussions I've had with myself, trying to legitimate my own conclusions.

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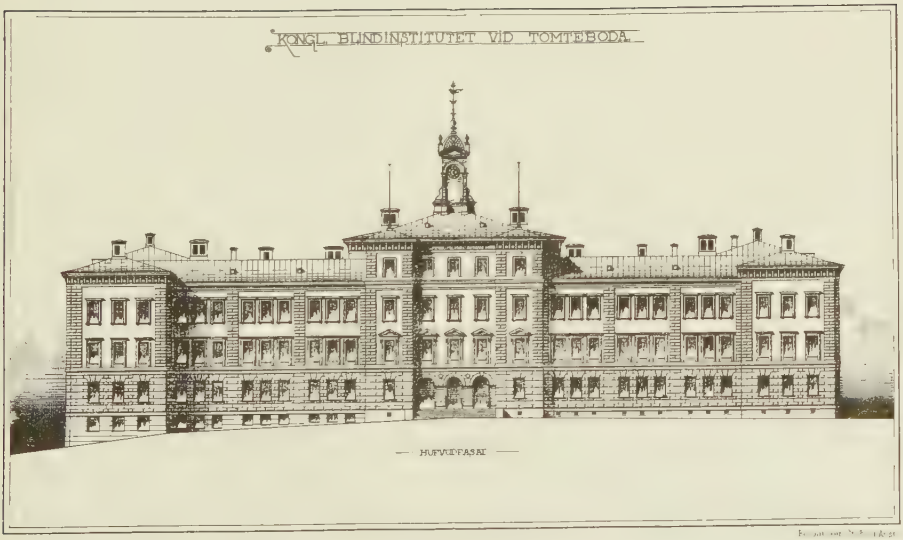
Uppsala, January 1978
Mats Myrberg

INTRODUCTION



1. Background

1.1. Changed patterns of special education

"*The right of the handicapped to receive special education*
Out of 36 countries:

2 refer explicitly in their Constitution to the principle of the right of the handicapped to receive special education (Guatemala, Italy). In many cases, however, the development of special education and its organisational principles have proceeded from the assumption that, in the absence of any indication to the contrary, the general principle of the right to education laid down in the Constitution extends as a matter of course to the handicapped,

22 set out this principle in texts which seem to come under the heading of legislation,

7 include it in texts which seem to come under the heading of regulations,

5 report no text on the subject. They do, however, have special schools and one country has set up within its central administration a special administrative unit responsible for organising and managing educating for the handicapped...

CATEGORIES OF BENEFICIARY

A. *Visually handicapped*
   1. *Blind*
   2. *Partially sighted*
      (a) other terms used
          Partially seeing (Canada, United States of America)
          Weak-sighted (Sweden, United Arab Republic)
      (b) Definitions
          b/60 to 6/24 of better eye after correction: United Arab Republic
          1/10 to 3/10 of better eye after correction: Sweden
          1/10 to 4/10 of better eye after correction: France
B. Hearing handicapped ..." (p 1)

This excerpt from a UNESCO Review of Special Education (UNESCO 1971) shows that there are legal provisions to ensure the right to special education for the visually handicapped in most countries. In addition, the pupils enjoying the right to special education are defined by means of their visual acuity. A visual handicap is thus considered a motive for special provisions in education.

In Sweden, as well as in most other countries, special schools (mostly boarding schools) have guaranteed the special educational provisions required for the visually handicapped. Specially trained teachers, special curricula and special

educational media have been concentrated in these schools. The Swedish special school for the visually handicapped (i.e. "Tomtebodaskolan") has a very high teacher/pupil ratio. The classes consist of about five to ten pupils. One extra school year is supplied to ensure that normal standards of competence in all subjects are reached by the visually handicapped pupils.

During the last decade there has been, however, a systematic trend towards instruction of visually handicapped pupils in regular classes instead of in special schools. Table 1:1 shows how the number of visually handicapped pupils integrated in regular classes has developed during the last 10 years.

Table 1:1. Number of visually handicapped pupils integrated in regular classes from 1966/67 to 1975/76 (Figures from the register of the RPH-SYN[3] lending library).

	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76
Comprehensive school:										
Class 1–3	0	0	0	0	0	3	5	2	1	6
Class 4–6	3	1	1	1		7	7	9	9	20
					43					
Class 7–9	18	23	28	21		29	21	32	46	38
High school:	22	21	24	37	45	56	56	47	43	43
"Folkhögskola"	21	28	36	46	61	59	57	67	59	41
Regional adult ed.:	4	8	8	–	40	50	56	59	70	88
Not classified:	7	27	46	104	38	24	25	20	29	19
Total	75	108	143	209	227	228	227	236	257	255

At the same time there has been an even more pronounced increase in the number of visually handicapped university students. The Swedish Association of the Blind began a study literature service for this category in 1963, with 4 students registered. This number had increased to 13 in 1965. The number of university students served by the study literature service in 1976 was 110, plus an additional 60 who attended courses of different kinds at an academic level.

Integration of visually handicapped pupils in the normal education system has been intensely debated since the trend began. The "pro's" are mainly beneficial social effects for the pupil, both in relation to peers and parents, and later on as increased capability to live an independent life. The "con" is decreased quality of instruction. Both sides seem to presuppose that the choice concerns the educationally most favorable setting for the visually handicapped pupil. An alternative way of looking at the integration trend is to relate it to changes in the social structure surrounding the educational system, and changes in the school system which special education is a part of.

Changes in the socio-economic context of education have brought about requirements on the school system which the special school cannot cope with.

Structural changes in the labour market have, for example, resulted in a decrease in the number of jobs with modest requirements on formal education, and an increase in the number of jobs requiring longer training and formal educations. Figure 1:1 illustrates this development.

The educational system has responded to these changes with a more differentiated school system, with greater emphasis on older children. In 1970 there were 46.5 % of the Swedish population who had only a seven year education or shorter.[1] Today the school system is dimensioned to give 90 % at least 11 years of schooling.[2]

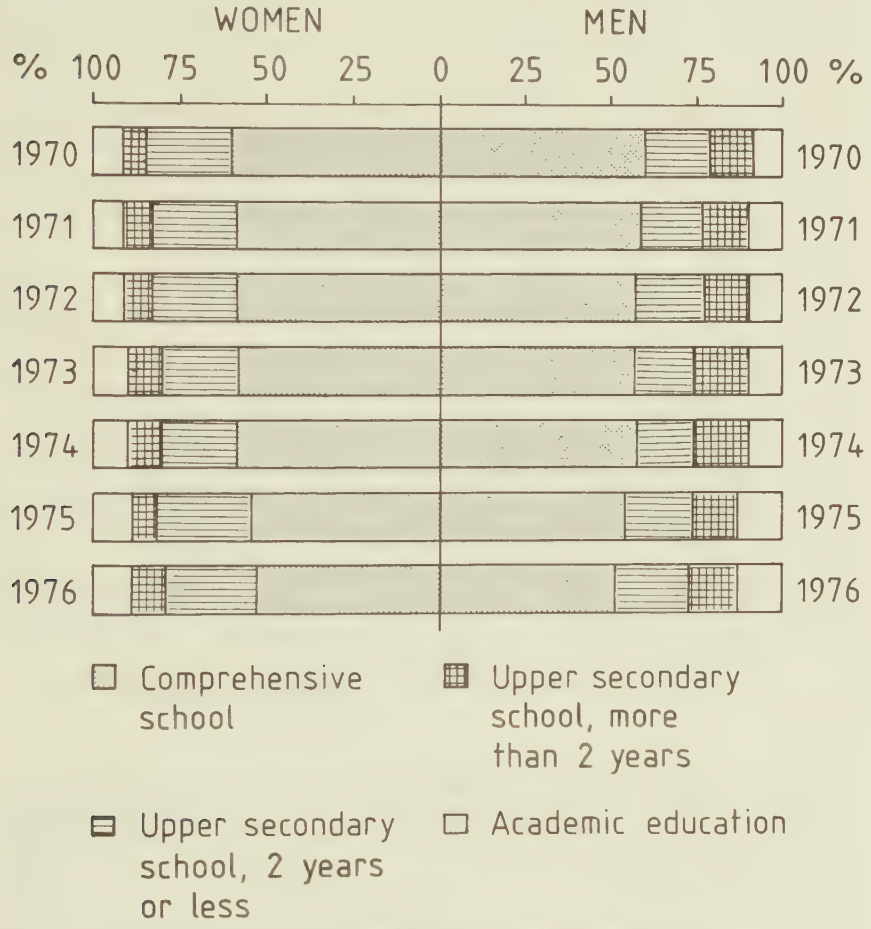


Figure 1:1. Educational level in the Swedish labor force 1970–1976.

[1] *SOU 1974:54. Vidgad vuxenutbildning.* Proposal from the committée for extended adult education (p 113).

[2] *SOU 1973:2, Högskolan.* Proposal from the educational committée of 1968. Stockholm 1973. (p 40).

The special school cannot supply a sufficiently diversified organisation to meet the necessary vocational demands which exist today. Already during the 8th and 9th school years serious problems are appearing when the pupils require the special school to supply all the alternative vocational branches. Far more serious problems would appear if the special school system were extended to the upper secondary level as well. The result of such a policy would rather be that the pupils were restricted in their occupational choice to a few professions, more or less arbitrarily considered suitable for the blind (An illustration of this "arbitrariness" is given by Myrberg, 1973).

The transfer of pupils from special schools to integrated education does not mean that the need for special educational resources for the visually handicapped has disappeared. Rather the case for special resources has increased. Individually designed educational material has to be provided for each pupil, an itinerant teacher service has to be established etc. Many of the pupils attending vocational education or academic courses may be the only visually handicapped pupils within their particular area. Nevertheless they must have the same basic resources as a whole class of visually handicapped pupils in special school education would require.

To provide the necessary resources a public committée in 1965 suggested that a special resource center for integrated visually handicapped pupils should be established:

> "The committee suggests that the 7th—9th schoolyear at Tomtebodaskolan is organised so it can provide the necessary aid to those pupils from the comprehensive school which are integrated in the regular school system, and furthermore provide aid for blind adolescents during continued studies and vocational training following comprehensive school. The committee therefore suggests that the present study literature library of Tomtebodaskolan is expanded to a educational resource centre.
>
> Considering, among other things that the number of blind pupils is too small to allow the establishment of special schools or permanent divisions at the high school level, it is urgent that the resources for pupils integrated in the regular school system are improved as soon as possible."
>
> (Prop 70, 5th march 1965, p 54. Author's translation)

As a result of the committee's proposal RPH-SYN[3] at Tomtebodaskolan was established as a resource centre for integrated pupils in comprehensive school and in upper secondary school. As we pointed out above (p 12) a corresponding service for visually handicapped pupils at the university level already existed at SRF (the Swedish Association of the Blind). These two bodies are mainly concerned with production of study literature in braille and as talking books. A lot of work is carried out on a joint basis.

The technical production of braille and talking book material is carried out by

[3] "RPH-SYN" is the abbreviation for "National Centre for Educational Aids for the Visually Handicapped", at Tomtebodaskolan.

"SRF Tal och Punkt AB" (mainly for the university level) and "AB Talinspelningar" and "LAN-produkter AB" (mainly for pupils in comprehensive school and upper secondary school). The books are then bought by the study literature library of the Association of the Blind and RPH-SYN respectively. TRU (the Swedish committee for Educational Broadcasting) produces some talking book material for adult education.

Prior to the technical production of the material the inkprint[4] book has to be re-edited. Editors at the study literature library of the Association of the Blind and at RPH-SYN decide how tables, figures, tables of content, etc should be presented in the talking book or the braille book. The editor also discusses how the material should be treated with the pupil who has ordered the material himself. The production figures for 1975/76 is shown in Figure 1:2 which also gives an outline of the relations between the different bodies engaged.

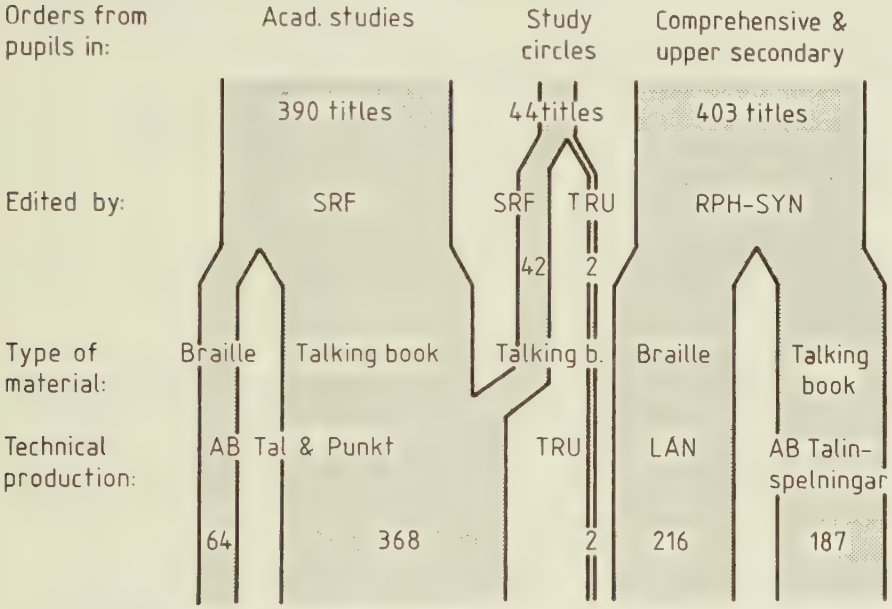


Figure 1:2. Production figures for study literature for the visually handicapped distributed on different producers (1977). Source: Personal communication with RPH-SYN and SRF.

[4] "Inkprint" is the conventional label for regular printed matter as apposed to braille among the visually handicapped.

1.2 The research project "PUSS"

Special schools for the education of the visually handicapped have several advantages; all necessary resources are concentrated in one school; the teachers are well prepared to instruct visually handicapped pupils; it is possible to design the physical environment in the most favourable way, etc. The integrated pupils and their teachers meet with difficulties in all these respects. The considerations concerning these matters revealed in the quote from the public committee report (p 14) show that such problems are foreseen. To get an overview of the difficulties facing integrated education of the visually handicapped, the Swedish Board of Education made research funds available for the purpose of investigating the study situation of the visually handicapped. The resulting project PUSS (which is an acronym for "Paedagogical investigations concerning the study situation of the visually handicapped") focussed on "problems concerning learning and study techniques connected to special instructional media. . ." (Lindqvist & Trowald 1970, p 1). "Special instructional media" in this context refers to talking books (studio recorded literature on magnetic tape) and braille books.

Other reading aids can, however, also be included: optical aids to utilise residual vision, different types of reading machines, computer produced synthetic speech, braille on magnetic tape cassettes etc. At the time the project started, ordinary braille and talking books were the only media available. The other reading aids mentioned above have been developed during the 1970's.

A first inventory of study problems among the visually handicapped gave the following ranking:

> "To get study literature on time" was considered the most serious problem. Next was "To find ones place in talking books", followed by "keep up with papers and journals", "review study literature before examinations, "comprehend descriptions of figures and tables", "to utilise dictionaries and encyclopediae", "to work with mimeographed material", "to read sufficiently fast", "to maintain concentration while reading talking books", "to make notes during lessons", and, finally "to be able to participate in written examinations".
>
> (Lindqvist & Trowald, 1971)

These factors were forced-choice response alternatives in a questionnaire distributed to visually handicapped studying at different levels. The alternatives were chosen according to viewpoints put forward by blind students in preliminary interviews and group meetings.

The problems mentioned above are almost exclusively *information problems*. Social problems, mobility problems and transportation problems have not been judged equally important. Some of the problems mentioned are dependent on the lack of ability to read inkprint. The problem considered as most severe, "To get study literature on time", has this background. This applies also to "To keep up with papers and journals" and "to utilise dictionaries and encylopediae". To manage these problems the visually handicapped students is referred to assistance by a sighted person, or to reading machines which make inkprint available to

blind readers. If the literature isn't available in readable form it's pointless to start looking at learning and study technique problems.

Other problems are dependent on difficulties in adjusting study technique to the special character of the talking book as an educational medium. This applies to "to maintain concentration while reading talking books" and "to make notes during lessons".

Still other problems are connected to the design of the educational material. "To comprehend descriptions of figures and tables", "to review study literature" and "to read sufficiently fast" are all problems dependent on the sequential character of the text representation in a talking book. In an inkprint text the reader can decide for himself how he is going to distribute his attention. He can repeat complicated passages, or skim through parts of minor interest. He can easily go forwards and backwards in the book to check references in the text, or refresh his memory.

The studies which will be reviewed in the following aims at mapping and counteracting editing problems when inkprint text books are transferred to talking book format. The main problem dealt with within this area is how graphical material should be handled by editors and narrators of talking books. The studies were initiated by the PUSS project.

2. The research problem

2.1. Talking book production

The Association of the Blind in Sweden has been engaged in the production of talking books for blind university students since 1963.

The number of blind students, and, consequently, the number of talking books produced have been increasing rapidly since the start. In 1966 there were 20 students registered and 250 talking books produced. The corresponding figures 8 years later were 150 and 3 180 respectively. During this period a lot of progress in production techniques have been made, and a lot of experience has been gained. The production of talking books has, however, also met with increased problems. Some of them are due to an increased demand for material, but quite a lot are also due to changes in the inkprint edition of the books. Such a change is the increased use of figures and pictures in text books which has appeared since talking book production was started. One of the problem areas of major concern for the PUSS project was, therefore, how graphical material in text books should be handled when the books were produced as talking books. The producers have had more and more trouble with the "transcription" of graphical material in the books: graphs, diagrams and illustrations of various kinds. The students often complained that they did not understand the verbal descriptions of the graphical material.

To make it easier for the reader to follow the discussion of problems connected with talkingbook production we will start with a short description of its organisation.

When a student gets his literature requirements from his teacher, he passes the book list on to the study literature library of the Association of the Blind. He encloses a specification of how he wants the book; on tape or in braille, with appendices, reference lists and notes left out or enclosed separately etc. The librarian in charge checks whether any of the books are already available in the library. The inkprint editions of the remaining titles are then passed on to an *editor*.

The task of the editor is to prepare the book for recording onto tape. You could say that the editor transforms the typographical lay-out of the book to connected discourse. He decides how tables, figures, footnotes, references etc should be recorded. He also decides if some of the material ought to be produced in relief or in braille. The editor then sends the book to a studio, where the actual recording of the book takes place. When a master tape is ready, a technical editing of the material is made. "Index signals", which can only be heard when the tape is rewound or fed forward at high speed are inserted at chapter beginnings. This

"index" facility allows the student to "scan" the book while searching for certain passages in the text.

The playing time of an average talking book of about 300 pages is around 20 hours. The resulting "reading speed" is about 175 words per minute. This is to be compared to visual reading, where the reading speed is about double for the average student. The possibilities to skim through passages judged less important are also very restricted in a talking book. There are technical possibilities to change the playing speed of the recorder up to 200 and down to 50 percent of normal speed, but still the blind student has a considerable reading handicap compared to his sighted study peers.

2.2. The representation of graphical material in talking books

The survey of study problems for visually handicapped students (Lindqvist & Trowald, 1971) revealed some serious shortcomings with the talking book. The students considered it difficult to scan the books, looking for a certain passage. They also complained that they did not understand the descriptions of figures, graphs, pictures etc. which were given in the book.

Most of the figures in the inkprint books are simply described verbally in the talking book. On rare occasions, plastic reliefs of very complicated figures are enclosed. The long manufacturing time for plastic reliefs however often makes it impossible to use this method. The student wants his book as fast as possible. Besides, many students do not master the technique required to read relief figures.

Verbal descriptions do, however, often get so complicated that the students complain that they don't understand them. In the abovementioned survey of problems with study literature blind students ranked the difficulty to understand figure descriptions as the fifth most severe among 11 mentioned. The Association of the Blind thus wanted some recommendations for the narrators as to how they should describe figures in talking books. The only existing recommendation, and the principle adhered to in proof reading, was that no parts or aspects of the figures should be left out. The argument was that the blind students should not lack information the sighted student had access to.

A typical figure description might sound like this:

> "There are three axes, one showing transfer effect, with nought in the middle, minus beneath and plus above. At nought is the point of identity, where the transfer effect is nought, as it meets the response similarity scale. The third axis shows stimulus similarity descending scale. An area of negative transfer is shown in a dark shaded area, starting in the bottom right hand corner, that is with minimum transfer effect, or where the transfer effect has the highest number, and where the stimulus similarity on the descending scale is at its lowest point, and an area of positive transfer is shown as a light shade area in the top left hand corner. End of figure."

You can see the figure this description refers to if you turn the page!

What then can scientific studies contribute to the solution of the problems of figure description in talking books?

The main function of scientific enquiry for the purposes we are discussing here is to guide practical action. This means that an accurate and verifiable description of the phenomena studied is of no use unless it can improve the quality of practical measures systematically. Surveys concerning the average comprehension of figure descriptions among blind students for example are thus not very helpful. The starting point must be theory, which makes it possible to predict difficulties, point out where the weaknesses in the figure descriptions lie, and monitor and evaluate effects of alternative description techniques.

The problem with a theoretical mode of working is, however, that action based on theory directs and changes theory as well as theory directs and changes action. A good formulation of the research problem leads to a theoretical reformulation of the problem as well as providing an answer to the practical problem. The new theoretical formulation of the problem at the same time implies reformulations of the practical problem and/or better methods to solve it. At the risk of getting lost in this iterative process, always spotting still greener grass on the far side of the hill, you have to stop the iteration at some point and try to make a major practical breakthrough in spite of the theoretical shortcomings that stick to the last problem formulation.

The dynamic relation between practical and theoretical formulations of a problem is reflected in the composition of this book. Neither the practical, nor the theoretical problem is the same at the end of the book as it is at the beginning. Three different theoretical problem formulations, all with different practical implications, are presented. The first two problem formulations have set off practical results in the production of talking books. The third formulation has resulted in a change of the practical problem. Other important, theoretically related problems are pointed out. As it places the problem of figure descriptions in talking books in a much wider context than the two previous formulations did, it does at the same time act as a point of retrospect in this book. The practical and theoretical implications of the third formulation for future research are explored to some extent, but are far from covered.

The book is divided into 3 sections, each corresponding to one theoretical conception of the problem. It is possible to read one single conception free from its context. This, however, does not reveal the dependence between the 3 different conceptions of the problem. Theories on human information processing is the common denominator for the 3 different conceptions. In this respect, they have a strong link to each other, even if the practical outcomes of the 3 conceptions do not reveal any apparent relation between them.

The first conception of the problem with figure descriptions in talking books sets out to find a description technique which might enhance the readers comprehension of the description. Design of the description was seen as the decisive factor. Consequently, the investigations made in this cycle aimed at determining

the effects of text complexity on the readers/listeners understanding of the text. Some attention was also paid to differences between visual and "auditive" reading with respect to the load it placed on the human reader.

Theoretical studies of differences in mental load between visual and auditive reading, however, led me away from the original problem. I began to suspect that the best possibilities to improve comprehension were in the hands of the editor rather than the narrator of the talking book. Verbal descriptions cannot fulfill the function of some of the figures in the inkprint book however good the descriptions might be. Recommendations for the narrators concerning description strategy could consequently not solve the problem. Rather, the editor's choice of representational form for the figure was presupposed to be the core of the problem. This second conception of the figure description problem aimed at ascertaining the effect of editing operations, primarily the effect of leaving graphical material out of the discourse.

Both the first and the second conception of the problem focused at the information conveyed by graphical material, and the reader's difficulties in acquiring this particular information. Some analyses of text books and talking book editing, however, seem to indicate that graphical material does not form a part of the discourse in the book in the same sense as the text does. The text often seems to be logically consistent almost without any graphical material at all. If the figures do not convey essential information which is not present in the text, the only reason to include them must be that they affect the reading *process* unfavourably. A third conception of the problem of figure description in talking books sets out from this postulate, and ends up with a perspective on the problem which has potential consequences for design of text material in general. Furthermore, this third conception presents a new theoretical perspective on the old research problem with educational audio-visual (AV) media. The theoretical framework of Conception III has practical implications for the blind in that it can guide the design of reading aids and media, making them able to mirror the logical organisation of the text in about the same way as the inkprint book can.

On the way towards a satisfactory theoretical formulation of the problem several practical recommendations have been suggested. As a result of the first theoretical conception of the problem a number of recommendations for the narrators were given. This was what the Association of the Blind originally wanted. The second conception gave rise to a number of recommendations concerning the editing of the inkprint book prior to recording. The third and final theoretical conception of the problem has resulted in recommendations concerning storage and retrieval of printed text in general for the visually handicapped. This approach considers the talking book in its traditional form as a special case, and recommends technical alternatives to store and display information for the visually handicapped.

The 3 sections of the book treats each one of these theoretical conceptions of the problems of figure descriptions in talking books. The theoretical formulation

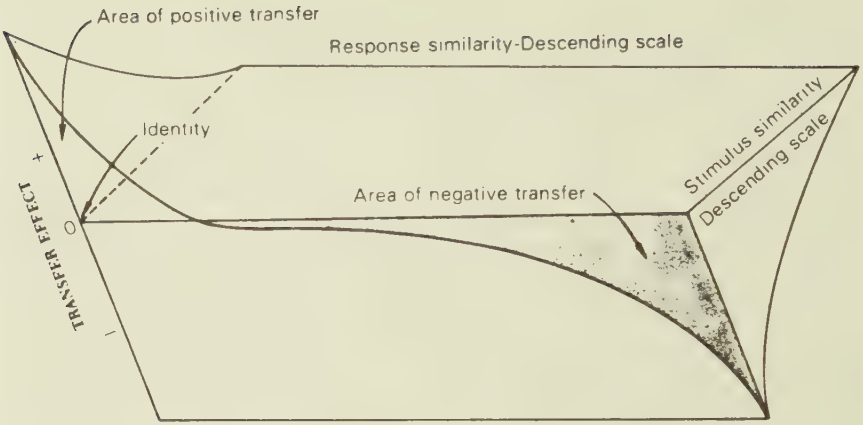


Figure 2:1. Figure taken from "Deese, J. & Hulse, S.H., The psychology of learning" (Mc Graw-Hill 1967), and described in a talking book for blind students of psychology. Figure description is given above.

of the problem introduces each section, together with an overview of relevant research in the area. This development of a theoretical conception treats several alternative possibilities and their relative merits and shortcomings. The following chapters in each section relate some empirical research based on, or closely connected to the theoretical problem formulation. The last chapter(s) in each section discusses the theoretical outcomes of the empirical investigations, and their practical implication. The consequences for the practical problems resulting from changing theoretical perspectives are also discussed.

CONCEPTION I
Mental Complexity of Information

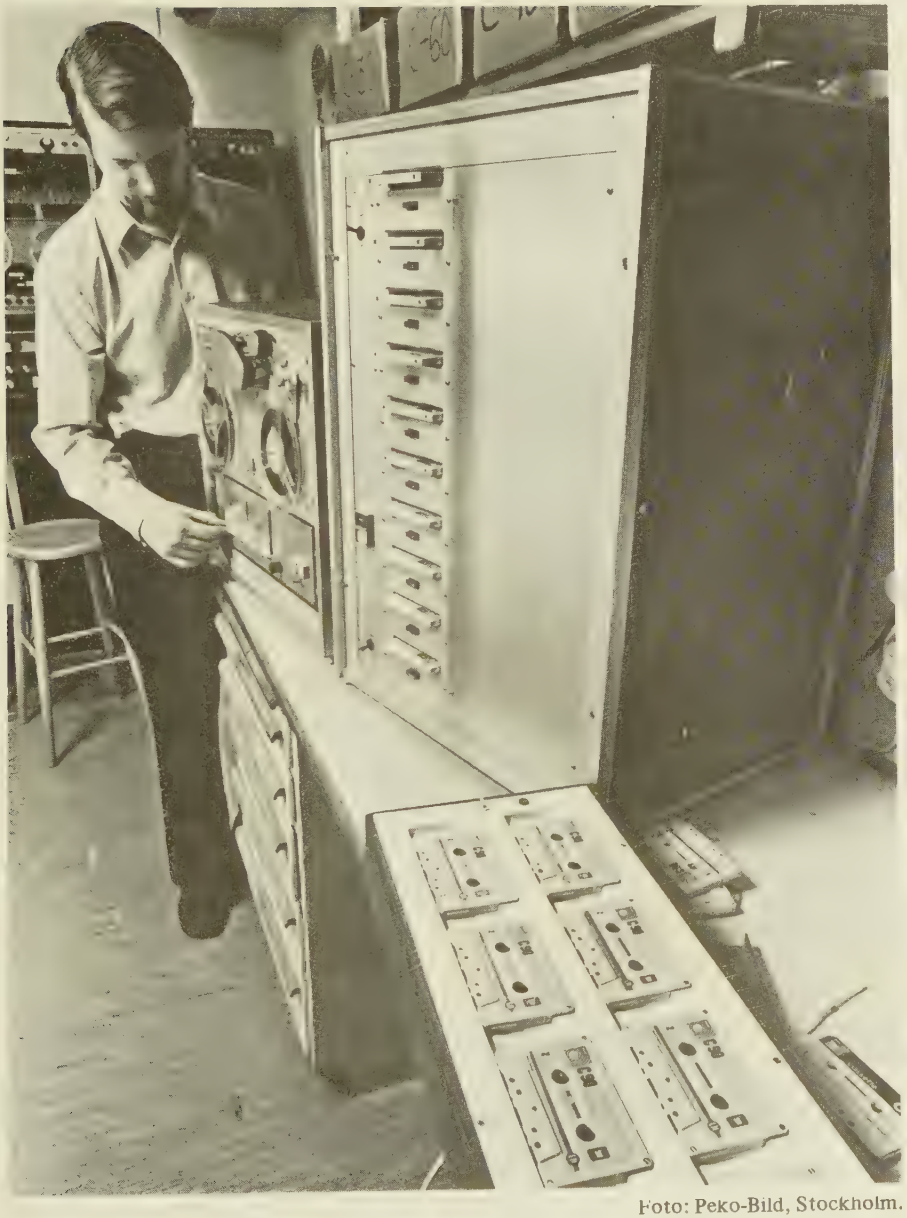


Foto: Peko-Bild, Stockholm.

3. Alternative theoretical interpretations of the problem

3.1. The practical problem

> "Figure description in talking books. How is graphical material from text books apprehended and retained when it is verbally described in a talking book? A talking book reader must get figures and diagrams auditively explained. How should this be done as effectively as possible? Is it more difficult to remember a figure when it has never been experienced visually?"

This quote is taken from the inventory of problems met by blind students which the Association of the Blind issued in 1969 together with the Department of Educational Research at the Teachers College in Uppsala. Behind this formulation lies the blind student's difficulty to understand graphical material in their text books when they are described verbally in talking books. Attempts to cope with these difficulties have not been successful. The narrators have been instructed to give very careful descriptions, and do not leave out any information which might decrease comprehension. In spite of this, the listeners' comprehension of the descriptions are still not satisfactory. The Association of the Blind therefore wanted to know to what extent the students really did gain from such descriptions, and how comprehension might be improved. Recommendations concerning suitable description strategies was one of the expected outcomes of a scientific investigation of figure descriptions in talking books.

3.2. Theoretical interpretations of the problem

The problem as stated in the "problem inventory" is actually a compound of questions. Each of the questions has different research implications. It is therefore necessary to choose one theoretical approach, thereby unfortunately eliminating several interesting questions. In choosing the question to investigate, the following considerations were judged as important:

1 "Is it interesting for the talking book producers to have the question answered?"
2 "Is it possible to get an unequivocal answer to the question?"
3 "Is there a theoretical formulation of the question which will give results which are also valid in other settings than the one studied?"

The requirements that the question should have an unequivocal answer and that it should be possible to give it a theoretical formulation coincide to an appreciable extent. The safest way to get an unequivocal answer to a question is to give it a theoretical formulation. The third requirement mentioned above is thus

actually a restriction of the second. You could very well apply methodological rigor to the investigation of a question without a theory to base it on. However, as unequivocal answers often are rather expensive, it would be unwise not to take advantage of the immense increase in information value the answer to a theoretical question would give.

Some of the questions which are hidden in the original problem formulation are:

1. "Is visual experience (or visual memory) a prerequisite to the understanding of verbal descriptions of figures in a talking book?"
2. "Is a visual image of graphical information advantageous to the retention of information compared to a verbal representation?"
3. "Is the *verbal* as opposed to the *graphical* representation of figures in talking books the determinant of their incomprehensibility, or is it the *auditive* as opposed to the *visual* reception mode that is the cause of the trouble?"

The possibilities to study these questions scientifically will be described in the rest of this chapter. The theoretical as well as the practical fruitfulness of each of the different approaches associated with the three questions will be considered.

3.3. Practical and theoretical implications of three different approaches to the problem of figure descriptions in talking books

"Is visual experience, or visual memory a prerequisite to the understanding of verbal descriptions of figures in a talking book?"

> "Out of individual or collective experience, symbols are invented to express the nature of experience. The symbols are expressed through visual design to project their meaning, and the meaning is responded to in terms of the readiness of the viewer. For example, a curiving line with an arrow point at the top means curving road ahead to most drivers. The symbol illustrates the problem of driving on a curving road. It communicates a shared experience. But to people who do not drive, or have had experience of driving only in flat open country, or have not seen such a sign, or have had very threatening experience with such driving situations, the symbol will communicate somewhat different things. A visual symbolic message is not a direct transfer of one person's experience to another person, but is mediated through each step from the initial experience of the sender to the response of the receiver."
>
> (King McFee, 1969, p 197)

This example shows that a common frame of reference is necessary if this kind of visual information is to be understood. Such a common frame of reference is often missing in communication between the visually handicapped and the sighted. This might very well be the case in many figures used in text books. The narrators task of making the "symbol content" understood to the talking book listener is futile if the meaning of the visual symbols are not shared between narrator and listener.

These kind of problems have been studied scientifically. The branch of science which has paid most attention to them is semiotics. Semiotics, however, has a strong link to cultural anthropology, which is why problems relevant to talking book listeners and their comprehension of graphical material aren't very frequent in the semiotic literature.

Some of the many psychological studies made on word associations might have more to contribute than semiotic research. Although it is true that these experiments use words as stimulus material rather than pictures, the experimental settings in many instances resembles that of a talking book recorder trying to describe a figure to his listener.

There are some experiments showing that "shared meaning" is easily communicated between speakers and listeners.

Rosenberg and Cohen (1966) have shown that standard word association norms are sufficient to predict details of speaker and listener behavior. The listener's ability to identify a correct response word can be predicted fairly exactly from such norms. This study used a setting where a referent stimulus was assigned to the speaker by the experimenter. The speaker's task was to provide a linguistic response that would make it possible for his listener to identify the referent stimulus. Rosenberg and Cohen claim that the same procedure can be used with nonverbal referent stimuli. They also refer to some experiments which have used this type of material. Krauss and Weinheimer (1964), for example, studied the way ambiguous figures were labelled by pairs of subjects who had to use the figures in cooperative problem solving. The main result of the study showed that the length of the labels (reference phrases) was proportional to the frequency of usage of a specific figure. The first time a figure is used it is rather elaborately described. When it has been used several times one referent word is often sufficient.

The interesting thing with the Rosenberg and Cohen model for the present purpose is that it presupposes minimal differences in subcultural background among the subjects. This is clearly not a valid assumption in all cases for talking book narrators describing figures to blind listeners (at least not if the listeners were born blind). If subcultural differences are a crucial factor to make predictions of communicability between speakers and listeners this might be a factor detrimental to the comprehension of figure descriptions in talking books. There are in fact a pair of studies of word associations among blind children which are relevant to the present problem. One study (Cutsforth 1932) concludes that 58 % of the responses of a group of 26 children described visual attributes of the stimulus word. A large number of the visual attributes mentioned were erroneous. Nolan (1960), however, failed to replicate this result.

The studies referred to above cannot be used to reject the interpretation that talking book listeners difficulties in understanding figure descriptions are effect of a lack of visual experience. They do show, however, that the problem is amenable to empirical study.

Olson's (1972 p 144) discussion of the relation between perception and language development might have a bearing upon at least congenitally blind talking book listeners difficulties with figure descriptions. Olson makes a distinction between sentences describing reality and sentences describing a propositional structure. ("Mapping sentences onto reality", and "mapping sentences onto sentences" are the phrases Olson uses to denote these two phenomena) which might be of relevance for the present problem also. The argument put forward is that coding of an utterance is intimately tied to perceptual acts at an early developmental stage. Children can handle complex syntactical relations if they have correlates in a picture, an event or some objects shown to them. Later on they also learn to apply the syntactical conventions for describing the logical essence of the picture. Furthermore, choice of verbal referents to describe for example objects in a picture is very much dependent on the context the object appears in. A big, white block is referred to as "the white block" if it appears together with a black block, and as "the big block" if it appears together with a small block. Subjects in these kind of experiments try to reduce the alternative interpretations as much as possible with as few words as possible.

The distinction between "mapping sentences onto reality" and "mapping sentences onto sentences" ought to apply for the "figure description" situation as well. It has been shown (Tobin 1974) that blind children tend to have a developmental lag concerning Piagetian conservation tasks which might very well be an instance of the problem Olson treats. The implications for figure descriptions are obvious; if a picture (showing reality) is described, the narrator must be very careful in his choice of discriminating cues in the description. The meaningfulness of describing these figures at all could be disputed, at least for talking book readers born blind. The case is somewhat different when it comes to descriptions of graphical material (diagrams etc). If the listener has acquired the reasoning ability, and the propositional structure of a sighted reader, he has the ability to comprehend a description *conveying the logical content of the figure*. It is doubtful if he can benefit from a description of the *design* of the figure, however.

A study of how visual referents in figure descriptions affect their comprehensibility is definitely interesting. Some interesting topics might be, for example, differences between adventitiously and congenitally blind, and changes in the use of visual metaphors as a function of time after the onset of blindness. Language development among blind children in this respect might also be worth studying.

The "semiotic approach" is however a little outside the focus of the present problem. The narrators are keenly aware of the potential dangers in the use of visual metaphors, so this is probably not the main cause of the listeners problems in understanding their figure descriptions. There are, however, other aspects of visual experience which might be necessary to enable the listener to interpret certain types of figures. Problems associated with the representation of three dimensions in only two is such an aspect. This problem is, however, far more acute when a figure is to be represented in tactile form. A verbal description does not have to

use the actual visual symbols used in the original version. If a description explains what the figure *looks like* rather than what it *represents*, it can hardly be understood by listeners born blind. This difficulty could be avoided if narrators are required to master the subject of the text.

Lack of visual experience as a determinant of the problems associated with figure descriptions in talking books might be an interesting *research* problem. The practical value of the outcomes of this research is, however, doubtful. The only practical way to meet this problem is to omit figure description for students born blind. This would, however, cause severe trouble for the talking book producers. It is not realistic to edit two different versions of the same book. Besides, to the extent the figures contain valuable information, students born blind would meet a definite handicap compared to adventitiously blind. Investigations originating from this question would not meet the requirements stated in the beginning of Chapter 2. They would *map* the handicap of blind students rather than *counteract* it.

"Is the visual image of graphical information advantageous to retain information compared to a verbal representation?"

Factors affecting the retention of material in memory has been a major interest for the psychology of learning and educational psychology ever since Ebbinghaus made his pioneering studies at the end of the 19th century. The results of this research is, however, not so easily applied to the present problem. Mentalistic concepts (as for example "image"), and studies using meaningful material were rare. The advent of behaviorism even made it unscientific to investigate the form of mental representation involved in the acquisition of information. Retention of material was considered to depend on the cumulative strength of stimulus-response connections built up during learning. In the margins of S-R psychology, psychologists of divergent theoretical conviction made some research on memory representations of relevance to this question. C.F. Bartlett introduced the term "image" to the study of memory-processes very early. Bartlett made extensive studies of changes in the memory trace during the 20's and 30's (Bartlett 1932).

Katona (1944) studied the relation between the organisation of material and human subjects ability to cope with it.

Carmichael, Hogan & Walter (1932) studied the effect of mental set on visual coding of figures. A set of ambiguous figures were given to two different groups of subjects. One group was given one set of verbal labels to the figures, while the other group was given a different set of labels for the same figures. The presentation of the figures was followed by a retention test in which the subjects were asked to draw the figures they had just seen. The results showed that the label attached to a specific figure affected the drawing. The two groups thus reconstructed the figures from their verbal labels, and not from their actual appearance in the presentation.

During the rest of the 1930's and the 1940's very little research was done on representation of meaningful information in memory.

The real break through, however, came with the introduction of research into mnemonic strategies. Already in the 1950's G.A. Miller was engaged on research into mental coding of verbal information (Miller 1951, 1956). The basic phenomenon studied by Miller was the strictly limited capacity short term memory had for storing information. This is in contrast to the everyday experience of the practically unlimited human capacity to store and handle information. Lurija (1968) has later treated the same topic, and discussed the implications of mnemonics for memory research. Somewhere between short term storage and long term stroage an extremely efficient coding of information must take place. Millers concept of "chunking" is an attempt to describe this coding. Miller, Galanter and Pribram (1960) presented a thorough discussion of how mnemonists overcame the limited information handling capacity. In accordance with Mandler (Postman, 1972, p 1) you can postulate that all forms of human information coding is restricted to Millers "seven chunks". From the sensory data impinging on human receptors, to the very basic categories of human knowledge, there is a "pyramid" of continous information packing in chunks. On the other hand, it is possible to postulate that the limited capacity of STM is only an "input-output" phenomenon, and that human storage capacity is in general practically unlimited.

During the 1970's, a theoretical debate concerning the coding form of information in human memory has flourished. Psycholinguistically orientated researchers have suggested that verbal information is represented as *propositions* in human memory (Kintsch 1972, 1974, Pylyshin 1973, Winograd 1972, Collins & Quillian 1969, 1972). This has been contrasted with another line of research, advocating *images* as the basic representation of knowledge in human memory. (See Paivio, 1974.) Although the two positions do not exclude each other, the proponents of each have started a lively debate on the topic.

The starting point of the "imagery" school is the clinical research done on clients with extraordinary mnemonic or eidetic capacity. The studies Lurija (1968) made on a professional mnemonist during a very long period suggest some very counterintuitive conclusions. Lurija's client had an almost unlimited capacity to receive and retrieve information, either it was verbal or pictorial. The rules governing learning and retention for him were totally anomalous compared to all earlier research on memory and learning. Concerning learning first, the only requirement for material to be learned was that it should be presented at a moderate rate. No repetition seemed to take place. According to himself, he used this slow presentation rate to load the material to be learned with sensory experience. He had very definite associations even with such meaningless material as numbers, which took on different sensory and emotional qualities.

The findings concerning forgetting are equally noteworthy. He had no difficulty in remembering material during very long periods of time. He said himself that his

major problem was to *forget* what was not important. When he occasionally made some memory lapse, it followed perceptual rules rather than memory rules. He could for example, during learning, associate material with a certain place he knew, but the lighting conditions in this place were so poor that he could not "see" the material clearly when he wanted to retrieve it.

Later research has shown that people with quite ordinary memory capacity also can profit from the "imagery technique". A typical imagery experiment starts with an instruction to the subject to form a pictorial image in connection to a trigram, or even visualize a whole list of trigrams within the same image. In most cases people do perform better with these kind of instruction.

The findings of imagery research could possibly explain the difficulties of blind talking book listeners to understand figure descriptions. If sighted listeners normally code descriptions of pictorial or graphical material in visual images, people blind from birth would be at a loss.

There are, however, some complications in this explanation. First, most imagery research has been carried out using meaningless material subsequently filled with meaning by the imagery technique. This is not the present case. The material to be understood is highly meaningful. Second, imagery research has shown the advantages of image coding for *retention* of material, not for comprehension (or even reception). Third, there are some findings (Jonides, Kahn & Rozin, 1975) showing that subjects blind from birth can also profit from imagery instructions. Images do not have to be visual to be effective.

Thus, it is not probable that difficulties in using imagery coding is the cause of the problems that blind talking book listeners have in understanding figure descriptions.

"How is graphical material comprehended when it is described verbally? How is visual material comprehended when it is represented aurally?"

The preceeding two approaches share one inherent weakness when rated against the criterion of applicability set up for an acceptable solution to the problem of figure descriptions in talking books: They can possibly *explain* the nature of the problem, but they do not offer any measure to counteract it. The explanation that "the descriptions cannot be understood by the blind because it takes visual experience and visual memory to manage this", and the explanation that "retention and comprehension of graphical material relies on visual imagery" both identify organismic variables as being responsible for the difficulties with figure descriptions. Inherent differences between the visually handicapped and the sighted with respect to their mental development are supposed to account for the difficulties. The direct implication of this type of organismic explanation is that the problem is unsolvable.

The third approach suggests another type of explanation: The factors responsible for the difficulties associated with figure description lie in the characteristics of

the talking book. Figures in talking books differ in two distinct ways from figures in inkprint books:

First, they are verbal representations instead of graphical (pictorial) representations.

Second, they are auditory representations, as opposed to the visual representation in the inkprint book.

These two differences make the reading situation of the inkprint reader quite different from that of the talking book reader, *regardless of whether the latter is sighted or blind.* Is there reason to believe that a sighted reader would comprehend a figure description in a talking book as poorly as the blind reader does? If this is the case, the factors governing comprehension of the description are to be found in the design of the reading medium, and not with the blind talking book reader.

Is there, then, anything that research can contribute to the exploration of this possibility? Verbal learning research (as well as learning research in general) has till about 15 years ago almost exclusively dealt with retention of information instead of reception and comprehension of it. Furthermore, the assessment of complexity of information or information processing has not been a central topic of research. Since about 1960 there has, however, been a growing interest in the structure of the human information processing system. This research could possibly contribute something to the problem with figure descriptions in talking books. In contrast to earlier research on verbal learning this "information processing approach" paid attention to acquisition of verbal material rather than retention of it. The difference in focus of interest might be illustrated in a conventional retention curve diagram (Figure 3:1).

In Figure 3:1, the traditional interest of verbal learning experiments is to study the influence on "a" of different variables. The information processing approach on the other hand, pays attention to how "b" is influenced by different variables. The gradual growth and decrease of a learning curve is seldom relevant when it comes to learning of meaningful information. Norman (1975) has put it the following way:

> "One thing concerns me about our understanding of the memory process; when I learn new material—such as the content of the papers presented at this symposium—almost none of this learning requires the kind of attentive rehearsal processes studied in the psychological literature on short- and long-term memory. I listen. I understand. And that is that. No rehearsal. No formal attempt to categorize or organize. Simply 'understanding'. If I fail to understand, then I will also fail to remember." (p 530—531)

This notion ought to apply for the comprehension of verbal figure descriptions as well as for the comprehension of a text. What is it, then, that makes the listener fail to comprehend and remember what has just been read to him? There have been several indices of readability constructed to identify the sources of difficulty in a text. A couple of them will be reviewed more thoroughly in Chapter 4. Long

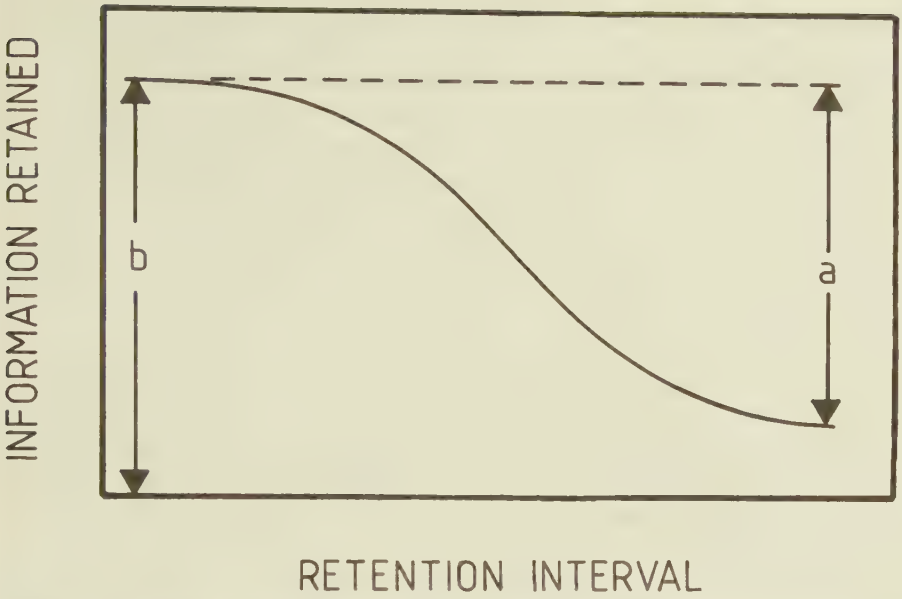


Figure 3:1. Focus of interest for traditional verbal learning research (a) as apposed to the information processing approach (b).

sentences, complicated sentence structure and many uncommon words, makes a text more difficult to read. Unfortunately, none of the indices relate their component factors to the actual reading process. Nor do they provide measures to improve a difficult text. The theoretical links to verbal learning research are very weak. This is, however, certainly due to the fact that verbal learning research mostly has delt with meaningless material. There is, however, another line of psychological research which might explain the effect of sentence length and syntactic complexity on reading comprehension, namely research on human information processing.

Donald Broadbent, who is one of the prominent figures in this field, evoked the notion of the human information processing system as a single channel as a consequence of his research on dichotic listening (Broadbent, 1957). The basic idea behind Broadbent's research, however, dates back to the very beginning of this century. "The principle of prior entry" (Titchener 1909) was the first formulation of the phenomenon. The main idea is that the human information processing system cannot handle more than one incoming signal at a time due to its very restricted input capacity. Exactly how restricted the capacity is was not investigated by Broadbent. There is, however, another classical research tradition, namely the notion of a restricted "span of apprehension" that might answer this question. It seems as the human being can receive vast amounts of sensory data at receptor level. The retina, for example, can convey 4.3×10^6 bits of information per second (Hunt, 1971, p 60). This information, however, decays after a very

short time delay (Averbach & Sperling 1961). The information then is recoded to an intermediate storage form. For verbal information this coding is literal. There is some controversy whether the information is coded in auditory or visual form (see Nilson, 1975, for a review of this controversy). The intermediate storage is denoted "short term memory", "primary memory" or "short term storage". Information can be retained for about half a minute in this form. Short term storage has a definite advantage from the "retention point of view" compared to sensory storage; the information in STM can be "refreshed" through active repetition without any further display of the information. This "proprioceptive" attention, however, requires mental effort which intrudes on storage capacity (Hollnagel, 1975, Lindsay & Norman, 1972, p 522).

Due to interference or decay (Atkinson & Shiffrin, 1971) information disappears from STM if it is not recoded once more. This succedent coding transforms the information in STM into semantic form. Semantic storage seems to have practically unlimited storage capacity. The problem here is rather retrieval from the unlimited storage.

How, then, could information processing limitations in the human short term memory account for the problems talking book listeners have in understanding figure descriptions? Why aren't the same factors operating when a sighted person reads an inkprint book? Why are the problems so acute for the talking book listener when it comes to graphical material? Shouldn't the same type of difficulties appear for connected discourse as well?

As far as connected discourse is concerned, the transformation to semantic form of the contents of STM is relatively simple. The syntactic rules for transforming the text into semantic form are well known by the reader, and do not require resources from STM. This applies both for the sighted and the visually handicapped reader and for readers of inkprint as well as readers of talking books.

When it comes to the semantic interpretation of graphical material, the matter is a bit more complex, however. There are no generally accepted rules for transforming the physical features of the figures to meaningful content. The inkprint reader can, in this situation, take the time he needs to interpret the figure. He can also judge for himself how detailed a comprehension he wants of the figure, thus breaking the transformation process at any point he likes. The talking book reader, on the other hand, has to keep the different constituents of the verbal description in STM unit he/she has created a meaningful whole out of it. This is probably done in much the same way as mental arithmetic is done, from the memory point of view. The storage of earlier described parts competes with incoming information for capacity in STM. This ought to create the observed difficulties in comprehending figure descriptions in talking books.

The methodological possibilities to study this tentative solution to the problem will be explored in Chapter 4.

4. Restrictions in the reader's capacity to receive and process verbal information as the factor responsible for poor comprehension of figure descriptions in talking books.

4.1 The mental complexity of figure descriptions

According to the description of man as information processor given above, the listener to a description of a figure in a talking book ought to have severe difficulties in understanding it. His task is to keep sentences in short term storage until he can recode them into a form more amenable to long term storage. The risk that he will get lost in the storage and recoding process increases as the amount of information, and the complexity of the recoding process increases. By instructing the narrators to make the description as careful as possible, and not leave any details out, comprehension might actually be *prevented* when seen against this theoretical background. As the mental load placed on the listener increases, the probability that he will understand the figure description decreases.

This approach to the problem is interesting both from a theoretical and an applied point of view. For the practical work with talking book production it offers guidelines concerning how to reduce the mental effort placed on the reader by different descriptions. It might result in recommendations concerning suitable description strategies to the narrators. Sentence construction principles might also be of importance.

From a theoretical point of view this approach offers good opportunities to study the human information processing system handling information in realistic situations. Very little is known about the factors governing comprehension of text, however. Most research has been done on meaningless material with verbatim recall as the performance measure. This limited basis of research is not, however, mainly the result of a lack of interest. Rather, it is a result of the methodological difficulties facing the researcher in this area. It is very difficult to control all factors interacting in the acquisition of natural text.

A theoretical explanation of the problems with figure descriptions in talking books according to the "limited capacity" view would focus on the psychological complexity of the figure descriptions. The solution to the problem would be to find the factors in the descriptions responsible for the complexity, and eliminate, or at least reduce them. The aim would be to find a description strategy to recommend to the narrators.

The methodological and theoretical possibilities to approach the problem with figure description in the proposed manner will be studied in sections 4.2–4.5.

4.2 Information measurement

Methods for measuring information first appeared in the theory of signal transmission. The applications were mainly in telecommunication systems of different kinds. The scientific study of information, however, soon evolved into a disciplin of its own. Shannon & Weaver (1949) describe the basic theoretical work.

The basic notion in the information theory of Shannon & Weaver is the measurement of *information value*. The probability of a signal is inversely related to its information value. This means that the better the signal can be predicted from already received signals, the less information it carries. The German expression "überraschungswert" (Frank 1965) for the phenomenon conveys its meaning quite clarly. If we imagine a Morse message consisting of many separate signals we can illustrate the meaning of some of the central concepts of information theory. If the Morse operator receives "a, b, c, d, e, f", "g" almost certainly follows. A "g" would thus have almost no information value. All other letters would be equally improbable, and consequently have the same information value. If the operator did not hear the signal following "f" he would probably guess it was a "g". If, on the other hand, he had received "b, e, q, r, b, o, i, w", he would be at a loss if we asked him to predict the next letter. Information value would be at its maximum. The difference between the two letter series from information theory's point of view is that the first one is *redundant*. It conveys information about signals not yet sent. Why then, should a message be redundant? Isn't it very uneconomic to make messages redundant? Instead of sending "a, b, c, d, e, f" you could just send "a, b, c, ...".

If we return to the situation where the operator missed a signal the reason for redundancy will be apparent. No channel, either human or technical, transmits all information fed into it perfectly. If we have a number of isolated letters sent by many operators at various times, we might get the pattern of received letters illustrated in Table 4:1 below.

Obviously, information is lost in the transmission from sender to receiver if isolated signals are sent. If all information sent had been received correctly there would only have been numbers in the diagonal of the matrix. All numbers in other cells signifies information loss.

If, on the other hand, we had sent "a, b, c,", "b, c, d,", "c, d, e," etc., there would probably not have been any loss of information at all. If the receiver had just got one of the letter in each consecutive triad correct, he would have been able to reconstruct the whole message wihtout any mistakes. The message would have been longer, more expensive and time consuming to both sender and receiver, but

Table 4:1. Information losses between sender and receiver of a message.

	a	b	c	d	e	f	g	h	Total number sent:
a	19	2	1	2	4	1	1	2	32
b	1	21	1	—	—	5	3	1	32
c	—	—	31	—	—	—	1	—	32
d	3	1	1	23	2	2	—	—	32
e	—	—	—	16	16	—	—	—	32
f	—	—	2	2	—	25	1	2	32
g	—	—	—	—	—	1	31	—	32
h	—	—	—	—	—	—	—	32	32
Total number received:	23	24	36	43	22	34	37	37	256

it would be correctly transmitted. In this way information transmission costs have to be weighted against redundancy.

More complex information patterns require more redundancy. On the way from the sender to the receiver a lot of error sources can appear. The sender could by mistake transmit the wrong signal, the technical equipment could distort the signal so it resembled another one, or the receiver could be mistaken. With the aid of information theory it is possible to isolate and measure these different sources of information. Thereby it is possible to strengthen the weakest link in the transmission chain. Information theory can not, however, tell you *how* to strengthen the link. If the technical equipment fails an engineer has to find out ways to improve it. If the sender or receiver fails, you can give them more training to increase their proficiency. In many cases, however, this is not enough to reach satisfactory system efficiency. Perhaps the limit of the human organisms performance is reached. Then you have to adjust the code, or reduce errors in other links in the transmission chain to get any improvement. Garner (1962) gives a detailed account of the methodology of information theory.

There has been much research on human performance in information reception and handling tasks based on information theory. Below we will review the relevant aspects of this research for the present purposes.

4.3 Psychological research on information complexity

The work of Shannon & Weaver (1949) gave psychologists new methodological tools for stimulus measurement. "Information value" is a useful yardstick in many kinds of experimental studies. Hyman (1953) studied the effects of information value on reaction time. Staniland (1960) made an overview of the general usefulness of "redundancy" in psychological experiments. Hochberg & McAlister (1953) used the approach to measure "figural goodness". Psychological research

with an information theory approach has been summarised by Attneave (1959) and Garner (1962).

After the "measurement era" a period of theoretical refinement of all the data started. At this time (at the end of the 1950's), a growing interest in psychological aspects of language and language acquisition merged with the "information complexity research". George Miller was one of the foremost names in both these research directions. The measurements of language complexity that he made in the early 50's made an essential contribution to the research into complexity of mental processes.

Miller, Galanter & Pribram (1960) pointed out that one of the main mistakes the "information measurement people" committed was that they tried to measure information complexity of a certain stimulus pattern quite aside of what the subject was supposed to do with it. They left the task requirements and the mental load exerted by information *processing* aside. Measures of complexity were often indices, composed of different physical characteristics of a stimulus pattern. The measures were mostly not validated theoretically. More often, complexity judgements were correlated with the physical measures to achieve a psychophysical scale of complexity.

This type of measure is not suitable for the purposes of this investigation. The function of a measure of "figure description complexity" is to assess the mental load it exerts on the reader. This means that the complexity of the mental processes required to understand the description is our major concern. The research done on the structural complexity of different stimuli is of little use. A certain set of simuli can represent quite different degrees of process complexity depending on what kind of task the subject is expected to perform with them. The complexity of a text passage for a person who is told to proofread it is, for example, rather different from the complexity of the same passage for the pupil who will have an examination on it.

4.4 Process measures of verbal complexity

The complexity of a text is dependent on at least three factors: the readers prior knowledge of the subject matter, the content of the passage, and the writing style of the author.

There has been a lot of methods devised to measure text complexity. Many of them, however, have the same flaws as the psychophysical measures of complexity treated above. The Swedish measure "LIX" (Björnsson 1968), for example, weights sentence length and the proportion of words longer than six letters into an index of complexity. The theoretical validation of the index is not very good. The validation methods used are correlational rather than theoretical (Backman, 1972).

A set of measures more related to information theory stresses the importance of redundancy in language. These kind of measures have the advantage that they

take account of factors inherent in all three "complexity sources" related above. The "cloze-procedure" exemplifies this category of measures. A number of words, drawn at random, are eliminated from a text. The remaining text is presented to a sample of readers who are requested to fill in the missing words. The degree of correctness they can achieve is an index of complexity. In this way all three of the complexity factors mentioned above can be studied. The authors way of writing can be characterised if a sample of texts from the same author is measured. The content complexity can be measured if a sample of authors versions of the same content is measured. The variation of complexity dependent on the readers prior knowledge is of course determined by testing the same text with samples of subjects differing in their knowledge of the subject matter.

The "cloze procedure" and other measures of this kind are related to both linguistic theory and information theory. Information theory has often been used to describe sequential dependencies in language (see for example Miller & Selfridge, 1950). The "guessing-game measures" also have strong relations to the "analysis-by-synthesis" model of language understanding (Matthews, 1967). Their relation to psychological theory is not equally clear. There are however measures of verbal complexity that have their origins in psychological theory also. The "overflow" method is an example of this. Savin & Perchonock (1965) devised a measure of sentence complexity along the following lines: the subject is presented with as many isolated words, trigrams or numbers as his STM could contain. Immediately afterwards he gets a sentence which he shall repeat back to the experimenter. He is also told to repeat as many of the isolated words, trigrams or numbers as he can remember. The number of lost items is an indication of the complexity of the sentence. Following Miller (1956) the original items represent about seven chunks of information. The complexity of the sentence can thus be ascribed a "chunk-value". A theoretical prerequisite to this procedure is also the assumption that no item can be retained in STM without (over or covert) repetition. This is, however, not very controversial. One of the most used methods for measuring information loss from STM, the Peterson & Peterson-paradigm (Peterson & Peterson 1959), relies on the same assumption.

The complexity measures founded on Miller (1956) and Peterson & Peterson (1959) primarily concern storage requirements of information. As we pointed out on page 38, the mental processes required to understand the verbal message is at least as important as the requirements on storage capacity. In the beginning of the 1960's the influences of Miller's (1956) work were still so strong that they focused the interest to information storage (cf Averbach & Sperling 1961). Partly as a consequence of Miller's own continued work the interest shifted to the complexity of mental processes (Miller & McKean 1964). This research tradition has been called the Derivational Theory of Complexity, or DTC. The main idea behind DTC is that a sentence of a certain syntactic form has to be transformed to a kernel sentence before it can be comprehended (Fodor & Garrett 1967). Depending on the test questions, both syntactic and semantic transformations can be in-

volved. Respone latencies reflect such transformations. Miller & McKean (1964), made a study of syntactic transformation which gave very neat results. Their experimental material was a set of sentences, which the subjects should verify (or falsify). The sentences could be put into several syntactic forms. The syntactic transformations used were active-passive, and negative-affirmative form. The result of the study was that different transformation added reaction time to each other. A negative-passive-transformation thus look as long time as a single passive transformation plus a single negative transformation. The response method used was to have the subjects confirm or deny a sentence.

The method of using response latencies as an indicator of mental processing, actually, has very old traditions. The first to use it was Donders (see Smith 1968) who hypothesised that mental processes revealed themselves in reaction times. More complex processes required longer reaction times. As RT research has found out later, reaction times are strongly influenced by mental set. This means that the subjects expectations concerning what meaning and content a sentence in the experiment has, affects the response latency very much. DTC has been strongly criticised on these grounds (Fodor & Garret, 1967). Mental processes are not as rigidly bound by grammatical form as DTC requires them to be. It seems to be impossible to describe sentence structure in terms of mental processes. This has also caused psycholinguistic research to place the emphasis on semantic factors. The increased interest in text grammars can at least partly be seen as a result of the insuffiency of sentence grammars to account for language comprehension and acquistion. This will be treated in more detail in the last section of the book.

4.5 The search for the unit of meaning

Millers notion of chunks as the mental units of information has also got successors. A very interesting coupling of Millers ideas with the research of Broadbent (1958) is examplified by Ladefogeds (1959) attempts to find a linguistic "unit of meaning". You could say that his research combines the storage complexity of Miller (1956) with the process complexity of Miller & McKean (1964). Ladefogeds studies are, in the same way as Broadbent's based on Titcheners "principle of prior entry". The human being is a channel for information processing and transmission which cannot handle more than one unit of information at a time. In Titcheners original experiment the subjects were required to mark the position of a pendulum exactly at the time when a bell was struck. Ladefoged replaced the pendulum for a text played on a tape recorder, and the bell for a "click-sound". The subject was asked to shadow the text aloud. At randomised points in the text, a click-sound was inserted. The subject was required after each click-sound to mark the position of the sound in the text. The rational behind this procedure was that the subject is unable to break a unit of text while it is in the processing stage in order to place the click-sound in its right position *within* the unit of text. The reported position should be directly *after* this unit instead.

Ladefoged did find systematic deviances between the actual position of the sound and its reported position. These deviances followed the syntactic structure of the text, at least to a certain extent. This issue has also been treated by Fodor & Bever (1965) and Miller (1962).

The search for linguistic factors responsible for the psychological complexity of language has also taken more explorative directions. A couple of syntactic characteristics of sentences been studied to assess their effects on comprehensibility. Coleman (1962) for example, studied the effects of recursive sentence construction on peoples ability to comprehend them. He found serious deteriorations in comprehension when extra clause levels were put into the recursive sentences. This fits in very well with later research on text grammars (see Section 10.1 and 10.2), which has pointed out that referential relations between different units in a text determines to a considerable extent the comprehensibility of the text (Chafe 1972).

4.6 What can earlier research contribute to the solution of the problem of figure descriptions? What remains to be answered empirically?

The research on information complexity has a great deal of relevance for the verbal description of graphical material in talking books. First of all, we could quite safely predict that shorter and less detailed descriptions would improve comprehension. There is, however, a need for more empirical investigation than the studies reported above. Just to tell the narrators to shorten their descriptions would not be of much help. The length of the description is probably correlated with the amount of information about the figure contained in the description. To shorten a description therefore probably means reducing the amount of information it contains. The aim of a recommendation to shorten figure descriptions must be to eliminate the information overflow the human information processor cannot handle. Unfortunately, the review of investigations on text complexity above did not result in a measure of complexity based on syntactic or semantic features which could be assessed theoretically. This would of course have been the ideal situation. If a narrator, during a description could keep a check on the mental load his description will exert on the reader while he reads it, this would be by far the easiest way to go. However, theory is not as far advanced as to allow this. While waiting for such developments on the theoretical level, we must rely on empirical studies of the effects on comprehension of different description lengths.

In order to give the narrators some guidelines concerning the relationship between description length and comprehension, an empirical study was made. The experimental procedure and results of this study are presented in Chapter 5.

5. An empirical study of the relation between length and comprehension of figure descriptions in talking books

5.1 Experimental procedure

As we have pointed out in earlier sections, there is strong empirical support for the hypothesis that comprehension of a figure description should decrease as the description length increases. The aim of further empirical study is not to give further evidence to this hypothesis, but rather to depict a limit in description length, where the human information processing system cannot cope with further inflow of information. This is illustrated in Figure 5:1 below.

Quantitative measures of the independent and dependent variables are necessary if the results of the experiment shall be described in a capacity diagram

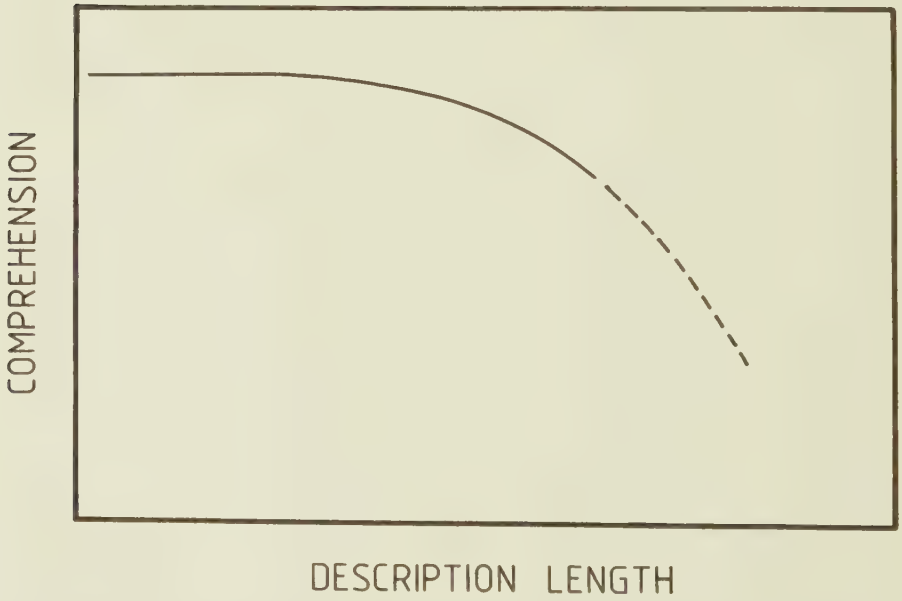


Figure 5:1. Hypothesised relation between description length (Amount of input-information to STM) and comprehension (Share of information retained of that fed into STM). Up to a certain load on short term memory the human information processing system can assimilate all of it. Above this limit the additional input cannot be coped with.

like the one in Figure 5:1. The independent variable in the experiment is *description length*. There is, however, certain difficulties involved in the experimental manipulation of description length. If a description in a talking book is shortened through deletion of—let us say—every fourth word, the complexity of the description is *increased* instead of decreased. This follows from the principle outlined in Section 4.1. If redundancy is reduced the information will become more difficult to handle for the human receiver.

Instead, description length has to be manipulated indirectly. The independent variable was manipulated through instructions to the narrator who described the experimental figures. He was told to make one detailed description and one crude description of every figure.

The dependent variable in the experiment is *comprehension* of the descriptions. This variable also poses some problems. If the measure of comprehension was that the subjects listening to the descriptions told, in their own words, what they thought the figures looked like, the result would probably have been crude repetitions of the crude descriptions and detailed repetitions of the detailed descriptions. This would of course not have been very informative. Instead a forced choice technique was chosen. The subject should identify one out of five alternative figures as the one just described. This could give a slight favor to the detailed descriptions as they provided more discriminative cues than the crude ones. Such an effect was counteracted by telling the subjects first to listen to the description, then to turn the page in the response booklet and mark the correct figure. The subject could thus not see the "response figures" while he/she listened to the description.

The choice of lures was also considered a critical factor in the experiment. Therefore, the experimental figures and their respective lures were chosen with great rigor. First, a sample of 40 figure descriptions were drawn from talking books already recorded. The figures and their descriptions were somewhat simplified to fit into an experimental setting. References to the text and details in the figures considered irrelevant to the purpose of the figure in the text were eliminated. The 40 descriptions then were read aloud to 20 subjects who were instructed to copy the figures as they imagined they had appeared in the printed book. The one of these 20 copies most resembling the original was chosen as the correct figure in the subsequent experiment. Among the other 19, four were drawn at random as controls.

Among the 40 different figures chosen in this manner, every second was included in the experimental material. The reason for leaving 20 of the figures out was that the experimental session otherwise would have become to long and tedious for the subjects. The figures were chosen so they would spread as well as possible over the variable complexity (subjectively assessed). The 20 experimental figures also were ascribed a more precise complexity value. The 20 figures were exposed tachistoscopically for 1/50 of a second to ten new subjects. This exposure time was chosen after a pilot session in order to avoid floor- and ceiling

effects. The 10 subjects were instructed to reproduce the figures as well as they could. The number of correct reproductions among the 10 was taken as an index of figure complexity.

The 20 experimental figures were described once more by a professional narrator with good experience of talking book recording. He was told to make two descriptions of every figure; one detailed and one crude.

The 40 descriptions then were replayed to 12 subjects with the task to pick the described figure among five alternatives on a response sheet. The subjects were told not to turn the page in the response booklet until the description was finished.

5.2 Results

The basic assumption that increased description length would give decreased comprehension, was confirmed by the results. The correlation (r_{xy}) between the two variables was $r_{xy} = -.60$, which is significant at the 1 % level. This result is in accordance with the earlier empirical and theoretical work we have described in Chapter 4.

The main aim with the experiment was, however, not to give support to a hypothesis which is already well established empirically. Instead, the aim was to assess a limit in description length where the human information processing system

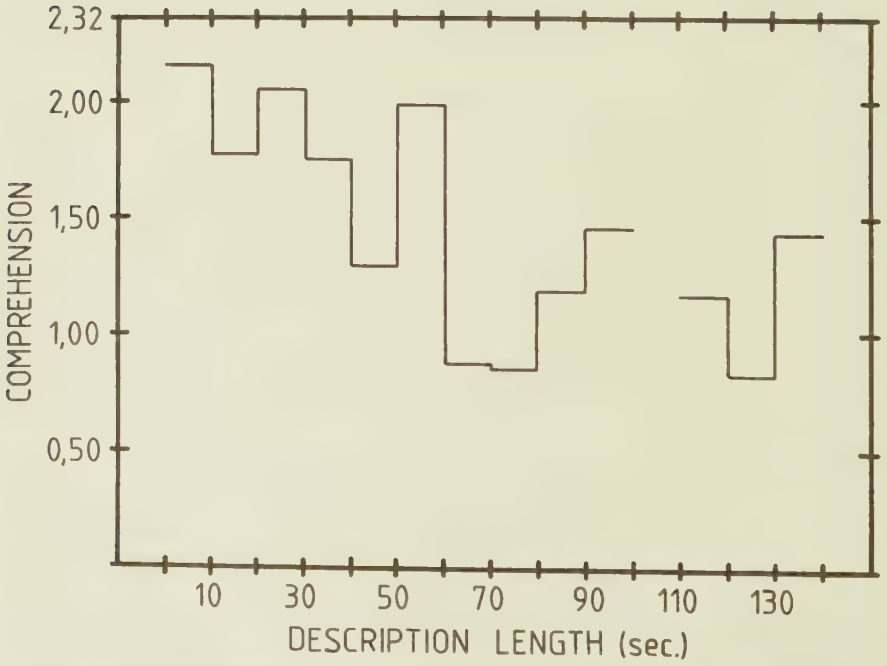


Figure 5:2. Relation between description length and comprehension (bits information conveyed).

could not keep up with information input. The relation found between description length and comprehension is depicted in Figure 5:2.

The relation between description length and comprehension is not as clearcut as hypothesised. There is, however, a pronounced difference in comprehension between descriptions shorter than one minute and descriptions longer than one minute. For descriptions shorter than one minute the average amount of information conveyed is 1.89 bits out the 2.32 bits theoretically possible. For descriptions exceeding one minute the corresponding figure is 0.99 bits. This might result from the capacity limit of short term memory which was predicted to give this result.

Figure 5:2 does not, however, take advantage of the fact that the experiment utilized a "mixed-list" design to rule out the effects of variables which might interfere with "description length". The absolute magnitude of "information conveyed" (comprehension) can therefore be ruled out. The effects of the two description strategies "detailed descriptions" and "crude descriptions" can be studied

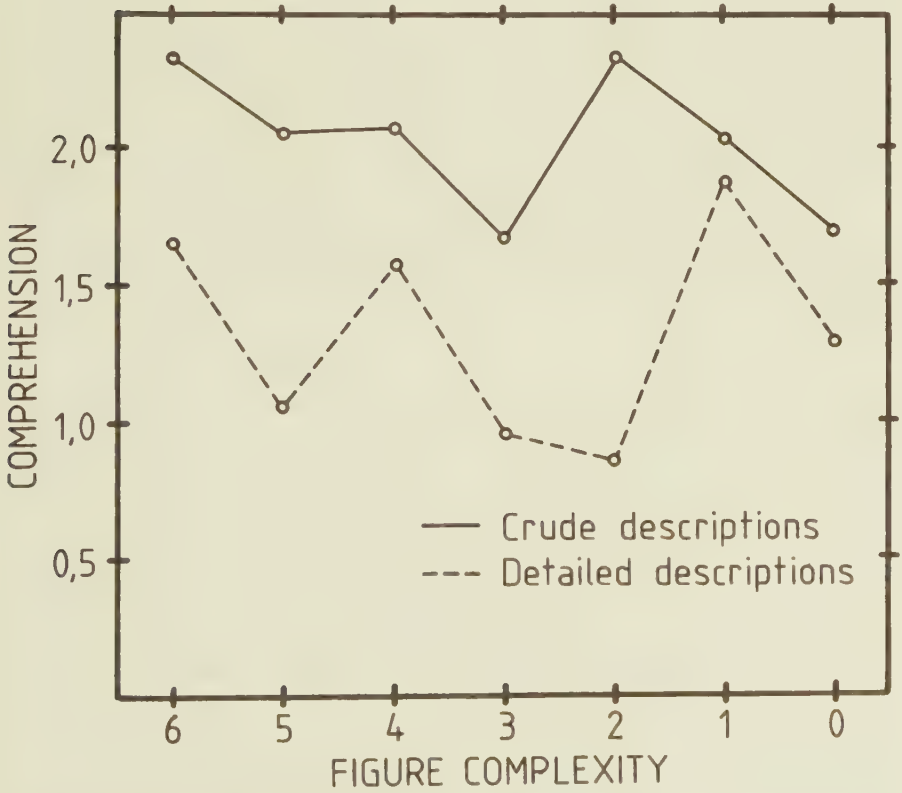


Figure 5:3. Relation between figure complexity (Number of correct reproductions in tachistoscopic exp.) and comprehension.

separately. It is, however, not possible to make a channel capacity diagram in the same way as in figure 5:1 for this relation, as there are no absolute magnitudes along the ordinata in the diagram. The hypothesis can, however, be reformulated to make it possible to use another type of diagram: "Crude descriptions will be an increasingly better strategy as figure complexity increases." It is necessary to assume a high correlation between figure complexity and description length (at least length of the detailed descriptions) if figure complexity should be able to act as the independent variable for comprehension. This correlation was estimated to $r_{xy} = .70$ for the relation between detailed descriptions and figure complexity, and $r_{xy} = .73$ for a calculated average description length (detailed and crude descriptions combined). The assumption can thus be said to hold.

The relation between figure complexity and comprehension of detailed and crude descriptions is shown in Figure 5:3 above.

The results depicted in Figure 5:3 do not support the hypothesis that crude descriptions are an increasingly superior strategy as figure complexity increases. No interaction effects between the variables detailed/crude descriptions and figure complexity can be traced in the data. The main conclusion to draw from Figure 5:3 is that crude descriptions have the same relation to figure complexity as detailed descriptions have. The crude descriptions give consistently better comprehension, but it decreases in the same way as comprehension for detailed descriptions. It could be said that crude descriptions widen the bottleneck in the human information transmission channel as the original hypothesis predicted, but they do not represent a solution to the problem of figure representation in talking books. Crude descriptions do not give a good comprehension even for the very limited figure complexity represented in this experiment. They are probably as incapable as detailed descriptions of handling the complex figures which appear in text books.

6. Evaluation of the "information complexity" conception of the problem

The literature studies revealed that syntactic factors influence comprehension of verbal material to an appreciable extent. There are also strong reasons to believe that the load placed on the reader/listener when he processes verbal information is one of the components mediating the effects of syntax on comprehension. The "information complexity" interpretation of the problem thus seems to be relevant.

The empirical study made to assess an optimal description length however pointed out certain weaknesses in the conceptualisation of the problem. The theoretical and practical issues evoked by the results of the empirical study are discussed below.

6.1 Theoretical interpretation of the results

The rational for making an empirical study was, as we pointed out earlier (p 42), that we wanted to assess an optimal information load in the descriptions. On the one hand, the descriptions must convey the same information as the original figures did. On the other hand, they must not exceed the human limits for information processing and storage. By pinpointing the relationship between comprehension and description length we should get a "knee" in the function showing maximum acceptable length. Beyound this limit, very little of the information in the descriptions would be understood.

Unfortunately, there is no "knee" or azymtot level in the relation between comprehension and description length. The experiment just supported the basic hypothesis; description length is a determinant of comprehension. The theoretical interpretation of this result is not quite straightforward. There are several sources of variance in the experiment which could blurr the relationship between description length and comprehension. Figure complexity, impact of experimental task and response method, instructions to the narrator, differences between individual subjects in STM-capacity, are all among these sources of variance.

Differential effects of STM capacity for individual subjects would be relatively easy to assess if STM capacity for the subjects participating had been determined in the experiment.

The reason why this was not done was that this would not be a very useful result for talking book narrators. It is not possible to make several alternative descriptions to fit different readers STM capacity. If the variance in comprehension due to individual STM capacity is large relative to the variance in comprehen-

sion due to description length, it would not be possible to recommend general measures which would improve comprehension of figure descriptions in talking books.

The variable "figure complexity" was controlled in the experiment so that it should not act as a source of error-variance. From the results reported on page 45 we can see that figure complexity in itself had almost no effect on comprehension.

The two remaining soruces of erroneous variance mentioned above are more difficult to cope with. Both "figure complexity" and the instructions to the narrators interfere seriously with the controlled variation of the independent variable STM load. The nature of this interference will be discussed in the next two sections.

"Instructions to the narrator" as an interfering variable

To attain a variation in description length, it is necessary to give some instructions to the recorder which will bring about this variation. It is rather likely that irrelevant factors are introduced in this instruction. It is not possible to instruct the narrator to give one description of a certain figure, and then manipulate the length of it afterwards. The problem is analogous to the one appearing when a too high LIX-value (Björnsson 1968) is to be reduced. If you just reduce sentence length, the text will be harder to comprehend instead of easier. What actually happens is that the redundancy in the text decreases.

Similarly a post hoc manipulation of the length of a given description will probably just complicate it. Both length and complexity is determined by the over all structure the narrator has given the description. Just varying the length does not change this structure. It just changes the redundancy of the description, thereby making it harder to understand.

In some way or another, the variation in description length has to be introduced through instructions to the recorder. This easily introduces qualitative factors which have nothing to do with STM load. One such qualitative factor which was probably operating in the present experiment is the effects of imagery treated in an earlier section. A quotation from the instruction to the narrator in the experiment might illustrate this:

> "According to one principle of description you should give a detailed description of the figures. Do not use any general concepts summarising several details in the figure. A curve diagram should for example be described with it's coordinates and not with it's general outline. [. . .]
>
> According to the other principle of description you should give a comprehensive picture of the figures. Try to summarise the figure in one or a few concepts. The total impression of the figure should be stressed at the cost of detailed information."

These instructions are not very different from what you can find in imagery experiments.

The results could be given an imagery interpretation as well as a STM interpretation. The variable "crude/detailed descriptions" is as strongly correlated to comprehension as the variable "description length". An interesting detail here is that only minute effects of figure complexity appear. The "imagery descriptions" might have levelled out the effects of figure complexity on comprehension.

Impact of experimental task and response method

The aim of the experiment was to bring about results that can form the basis for recommendations to talking book narrators concerning figure description techniques. It ought to be possible to generalise the results from the experimental set-up to the situation facing a talking-book reader.

This requirement on the set-up is to a certain extent violated with the response-measured used. A talking-book reader mostly has to construct a mental conception of some kind of the figure that is described. This is not necessary in the present experiment. As a recognition method is used to measure comprehension of the descriptions, it is sufficient for the listener to concentrate on a few cues that discriminate between the target and the lures. To avoid such effects the subjects in the experiment were instructed *not* to turn page in the response-booklet, or look at the response-alternatives before the verbal description had ended. The "discrimination character" of the experimental task probably still remained to a certain extent. The fact that no interactive effects in the predicted direction between figure complexity and the variable "crude-detailed description-technique" appeared could be a sign of this.

The discriminative cues in the descriptions, which perhaps aided substantally in the experimental task, would be of no value in the comprehension of a description in a talking book.

The sample of figures used might not represent the population of figures encountered by the talking book reader. The figures used in this experiment are very simple compared to many figures appearing in text books. For purely practical reasons it is not possible to choose more complex figures. On the other hand the aim of the experiment was to decide a limit on the "complexity" scale, where the human information processing system couldn't keep up with the information load any more. This means, however, that we are at a loss when it comes to the most complex figures in the text books. If crude descriptions can only be recommended for simpler figures, the narrators must have some guidelines to categorize figures as simple ones amenable to verbal description, and complex ones requiring other means of representation. This implies that one of the main research problems in connection with figure-descriptions has not been treated at all in this experiment, namely the choice of form of representation of the figures. It was "postulated" that verbal descriptions would suffice if they were made according to an efficient description strategy. Problems related to choice of representational form was therefore analysed further in a new theoretical paradigm. These analyses form a

new conception of the problem with comprehension of figure descriptions in talking books.

6.2 Practical outcomes of Conception I

Despite the partly negative outcome of the experiment with figure description strategies related in Chapter 6, there are some valuable conclusions to be drawn from Conception I.

The empirical study has shown that detailed comprehension of verbally described figures is an unrealistic level of aspiration. The talking book readers comprehension will suffer severely from longer descriptions than about one minute.

Some conclusions can also be drawn from the research on verbal complexity referred in Chapters 4 and 5. Readability measures, for example, could be used to evaluate the comprehensibility of figure descriptions.

A narrator can rather easily find out if his descriptions are unusually complex. The LIX-measure referred to earlier (Björnsson, 1968) is the easiest to administer. A text version of the description is prepared and LIX is calculated from it. If the value exceeds 50, the description ought to be done in a simpler way. As we pointed out on page 38, the LIX-measure has no theoretical basis, so we cannot tell exactly what is wrong with the description from a high LIX-value, just that something ought to be done.

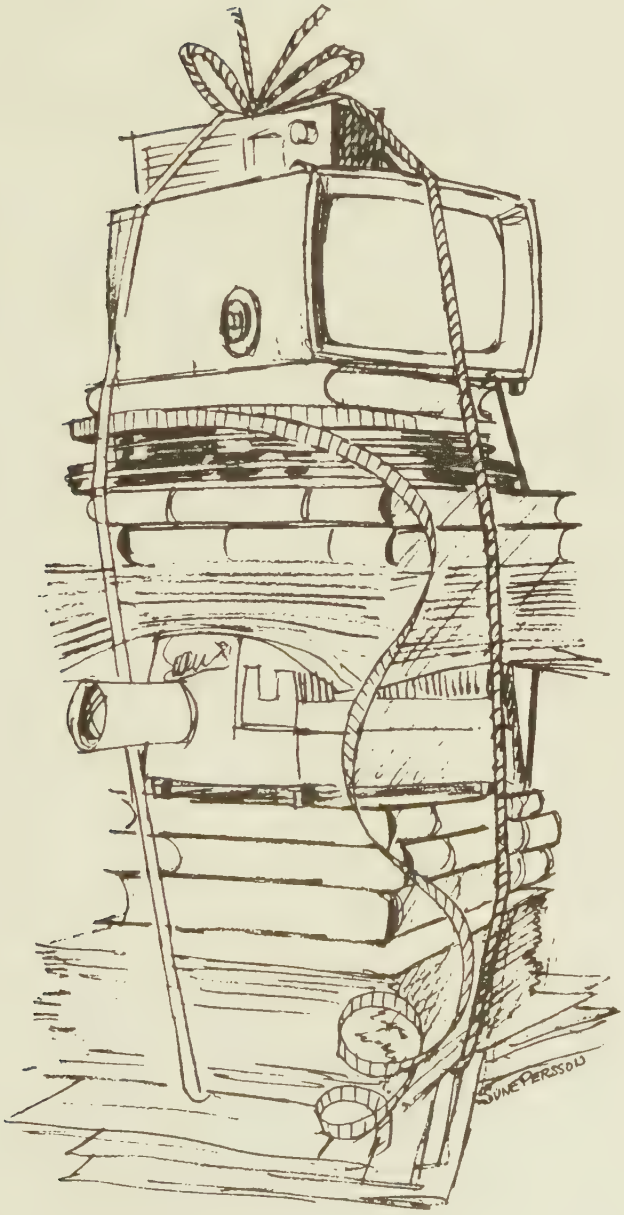
There are also theoretical possibilities to recommend certain steps to enhance comprehensibility of a description. The studies by Coleman (1962) are relevant here:

- Recursive sentence structure must be avoided.
- Pronouns should not be used, even if repetition of the word referred to ought to be avoided for stylistic or grammatical reasons.
- One and the same label should be kept for the same phenomenon throughout the description.
- Active form should be preferred to the passive. Negative constructions should be avoided.

The imagery research reported in Chapter 3 also has practical consequences for figure description:

- Introduce the description with a general "overview" of the figure. This can act as an image to attach details to later on.
- Use unifying concepts or metaphors to build each description around. Of course these metaphors must not refer to visual experience.

CONCEPTION II
Visualisation of Text books



7. The problem

7.1 Resume of Conception I

> "Figure description in text: A blind student has to get figures and diagrams explained auditively in talking books. How should this be done most effectively? Is it more difficult for a visually handicapped person to remember a figure because he has never experienced it visually?"

This original problem formulation is quoted from the review of study problems for blind students issued by the Swedish Association of the Blind (SRF). It was reformulated into a research problem with the following wording: "Do verbal descriptions of graphical material in talking books overload the human capacity to handle verbal information. Is it possible to device a descriptions strategy which reduces this load?"

An empirical study of the abovementioned problems demonstrated that the sort of detailed figure descriptions which were used in talking books did overload the human capacity to handle verbal information. An alternative description strategy lessened the load to a certain extent. A general conclusion of the study was however that verbal descriptions could not give a satisfactory comprehension for the many rather complex figures which appear in text books. Complex figures require other means of representation. Moreover, the task the pupils are supposed to perform with the figure is an important determinant of the mental complexity the figure represents for the reader.

These conclusions change the research problem radically. If verbal descriptions are insufficient for many categories of figures one of the main problems must be to choose the form of representation for the figures. Factors guiding this choice are analysed in Conception II.

7.2 A new conception of the research problem and its practical and theoretical implications

The experimental task, and the variable "figure complexity" turned out to be a lot more central to the problem of figure description than was expected initially. The independent variable in the foregoing conception, "description length", is not possible to manipulate independently from "figure complexity" and "experimental task". The missing link in the previous conception of the problem is thus the educational intent behind a figure in a text book. The aim with the present enquiry into the problem must be to find ways to preserve this intent in the new representation of the figure in the talking book. An absolute requirement is that the results

point at ways to counteract the study handicap caused by visualisation. A mere analysis and mapping of the handicap is thus not sufficient.

The main question to ask when we want to assess the study handicap which graphical information in text books causes the blind students is how *essential* this information is in the books. The first conception of the problem showed that most of the information in text book illustrations is lost when it is described verbally. What would happen if all graphical information was deleted from the books? How much, and how valuable information do graphs and pictures contain? If a study revealed that the information conveyed by illustrations is of very marginal importance, the handicap of the talking book reader would be correspondingly small, irrespective of the description difficulties.

The practical measures and recommendations resulting from the second conception will have to go a step further than just recommendations to narrators concerning the description of the figures. As was shown in the first conception, verbal descriptions are insufficient for conveying graphical information. Other measures must be taken. In some cases the figure is perhaps of very little importance to the discourse. It can be left out without any further consideration. In other cases the figure perhaps contains detailed, very valuable information to the reader. It has to be represented in a way so that the reader can take his time studying it in detail. Such considerations have to be made *before* the books come to the recording studio. There is no time for making these judgements there. There is a need for a re-editing of the inkprint book *before* it is sent to the narrator.

When recording of talking books for blind students first began, narrators had to prepare the figures themselves in advance. At about the time when the studies in the first conception of the figure-description-problem were completed, SRF hired an *editor* who should take care of the preparation of the inkprint book. Such preparation can include contacts with the student who ordered the book in order to learn about his/her special requirements; whether the book should be produced as a talking book or in braille, whether appendices should be included etc.

Judgements concerning the representation of figures is also within the editor's field of responsibility. Practical recommendations resulting from this second conception might therefore be directed to the editor of the book instead of to the narrator. If the aim is to judge the *function* of the figures in the books, the editor has better possibilities to do this than the narrator has. Conception II thus aims at giving recommendations to the editor concerning the treatment of graphical information in text. This is a wider scope than the first conception. The research task to analyse the human ability to cope with information designed in different ways still remains, but is preceded by a stage that might turn out to be an analysis of text representation as well as an analysis of graphical representation.

This new approach to the problem is not, however, a radical detour from the former. Rather, the first approach has given birth to the second, partly through the conclusions of the empirical study, partly through the first theoretical formulation of the original problem. As early as the initial deduction of the problem, it was

1) "An example of the circulation of nutriments in nature" (Siljeholm, I. Biologi 1, grundkurs. Hermods 1975, p. 58).

2) "The circulation of nutriments between organisms and ecology" (Linnman, G. et al. Biologiboken för högstadiet. Esselte 1975).

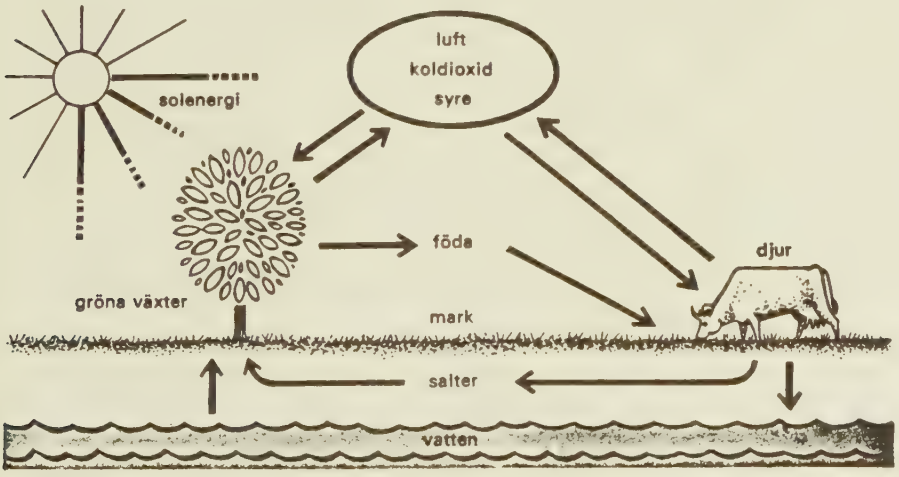


Figure 7:1. Two figures of different complexity, illustrating the same phenomenon.

clear that the *physical* complexity of the figures was of minor interest in the assessment of their "mental complexity". Consequently, the mental operations performed by the reader when he tries to comprehend the figure were chosen as the basis for the measurement of complexity. Further, we wanted to point out that the mental processes required from a person listening to a spoken figure description put a greater strain on human memory than the mental processes required from the spectator of the original picture. The mistake in the first approach to the problem was, however, to try to measure the complexity of the figures apart from their discourse context and the author's intention with them. You could very well imagine an exceedingly complex figure with many details of very minor educational significance in a book. You can also imagine two absolutely identical figures representing two radically different complexities due to their context.

Without the context it is far from evident that the two figures above illustrate the same phenomenon (the circulation of nutritment in an ecological system). The first illustration is far more detailed than the second, but it would be pointless to include any more details in the description of the first one than in that of the second one (Figure 7:1).

As can be seen, there is no point in trying to reduce the educational handicap of blind students by uncritically trying to reinstate all the information contained in the visual representation in the auditors one. Instead, you must assess the educational function and value of the figure. If a narrator has to leave the figure out because it is too complex to fit in the frames set by Conception I, it is not possible to know anything about the educational consequences for the student reading the book without the figure later.

Chapter 8 will introduce the assessment of educational value of graphical material with an analysis of the concept "visualisation".

8. Visualisation, its meaning and educational value

8.1 Definitions of visualisation. Methods to cope with it in the education of the blind

Visualisation of education is a multiple concept. Three different meanings of the term can be distinguished:

a) Visual representation of educational information is replacing auditory representation. This type of visualisation is reflected in an increased use of visual media in education: Educational television, films, selfinstruction materials etc. The type of visualisation has, aside from its possible educational advantages, been claimed one of the prerequisites for individualisation of education. As instruction is individualised to a greater extent, more teachers are required to manage the new patterns of instruction. As teacher's salaries are more expensive to the school than visual media, teachers are replaced by visual media. The "visualised" organisation of instruction is not more effective by bringing about better educational results, but by giving the same results as before, but at a lower cost.[1]

b) Information is not presented in *verbal* form in education as frequently as earlier. Pictorial and graphical representations are replacing verbal representations. McLuhan (1962) predicts a further development along these lines due to changed information techniques and communication patterns. There are, however, also educational motives, aside from cultural changes, for an increased use of graphical and pictorial representations as alternatives to verbal ones. The pictorial mode is said to increase motivation (cf page 101) and support long term retention (Shepard, 1967). An increased need for graphical representation could emanate from a change in educational objectives from merely fact reproduction to analysis and synthesis of structures. These could not, then, be conveyed as well in words as in graphical form.

c) The third form of visualisation means that the *goals* of school instruction are changed from merely cognitive, which lend themselves to verbal representation, to affective, which requires all the senses to participate in the reception of the educational messages. The "visual literacy" movement is representative of this.

[1] It can be questioned whether this argument stands up to scrutiny. Experience from Swedish tests with educational television (SOU 1973:19) shows the opposite.

All three versions of visualisation related above cause educational handicaps for the blind student. Depending on which form of visualisation the student is confronted with, different resources are required to counteract the resulting handicap.

Which measures it takes to meet the first form of visualisation ("individualisation through visual media") depends on the form of special education which is concerned. For the visually handicapped instructed in special schools ("residential schools") this is no problem. As we said above, this form of visualisation aims at making individualised instruction possible without increased resource consumption. For visually handicapped pupils in special schools it must be accepted that a need for extra educational resources remains. One school year is for example added for the visually handicapped pupils in comprehensive school in Sweden. The classes are also considerably smaller: 5—6 pupils per class compared to about 30 per class in regular school. In fact, individualised instruction seems to be in use already. Of course it would be desirable to increase efficiency in the special school anyhow, but the pupils are not primarily affected by it. From the teacher's point of view it would, however, be desirable to offer alternatives to the time consuming tutoring with which the teacher of the blind has to replace media instruction.

On the other hand, when visually handicapped pupils are integrated in classes with sighted peers the problem of "visualisation media" immediately increases. The visual methods of "rationalisation" are used regularly in the classroom. The teacher cannot abandon them altogether in order to adjust his instruction to the visually handicapped pupil. The curricula presupposes the use of certain media and certain methods of instruction which the teacher is unable to replace. The teacher's possibilities to influence the actual conditions of instructions are small, as the methods of instruction and lesson plans are decided at an earlier planning stage. Acute problems for the visually handicapped pupils could, for example, appear if educational films, or illustrations in books are used to replace real objects and instruction in "live situations".

Substitutes for visual media are thus, to a great extent, missing in education for the visually handicapped. The cause of this is not that they are considered unnecessary, but that the technical problems in constructing new media for the visually handicapped in school are very severe. As the target group is also rather small, thus the costs of technical development would be rather high per produced unit.

The second form of visualisation (replacement of verbal representations by pictorial and graphical ones) is not possible to overcome in the same way as the first form. Representations, which are tactually or aurally available, have to be created if the visually handicapped pupil is to profit from this type of instruction.

As we have shown in Conception I above, the way used to meet this kind of visualisation in talking books does not work very well. It is not quite clear though, what the exact advantages of graphical/pictorial representations over verbal ones actually are. This is a question of major importance if we want to reinstate the function of these representations in text books as well as in media for the blind. Do

the new forms of representations *replace* old ones, or do they *interact* with them to give increased clarity to the discourse? Are they favourable to *retention* of the material, or are they advantageous to the *acquisition* of it? The former case would change the course of investigation from studies of transient storage and processing that were initiated in Conception I to research on imagery and mnemonics.

The third form of visualisation is not actually "visualisation" in the same sense as in the two cases above. Rather, it concerns a form of "deverbalisation" or "deintellectualisation" of education. The rational is that "verbal" information does not give the full blown experience of the concepts to be taught. The affective components of knowledge must be stressed if it should be internalised by the pupils.

The problem for the visually handicapped pupil is, in this case, of another character than in the two former "visualisation cases". Cutsforth (1932) has pointed out that visual aspects of concepts often are repeatedly stressed by the blind. In accordance with the "visual literacy" argument they get a rather superficial knowledge compared to their sighted classmates. There is no one, to my knowledge, who has tried to devise measures to counteract this state of affairs, or even tried to analyse the consequences of it for the blind.

The rest of Conception II will be devoted to an analysis of different aspects of visualisation, and different ways to level out the negative consequences for the visually handicapped. The second meaning of the concept as related above will be the basis for an analysis of the information losses the visually handicapped pupil suffers compared to his sighted peers.

8.2 The illustration of text books

The use of graphical material in text books is not a new phenomenon. The first "illustrated" school book was Comenius' "Orbis Pictus". This Latin reader from the 17th century was for almost a century the most popular Latin text book in European schools. The rationale for using pictures in the book was twofold: first, Comenius wanted to use the children's experience of everyday life objects, familiar to the child, as the basis for instruction. Second, the didactic technique was to have them repeat the illustrated words when the teacher read them aloud. The illustrations were thought to amplify the association between the written word and the spoken.[2]

The illustrated book of the 17th, 18th and 19th centuries was, however, very expensive to print. As long as the pupils came from well-off families, this was not a major problem. Many of the text books for secondary school are furnished with pictures (cf Almqvist & Lagerstedt, 1878). Pupils in compulsory school couldn't, however, afford any educational material except the catechism and a slate.

[2] This "whole word technique" of teaching children to read is in fact very traditional. The "spelling method" is a 19th century invention (Huey, 1908).

Table 8:1. Development of number of illustrations in 12 editions of "Folkskolans läsebok". (From Lindström, 1957, page 2).

(Year)	Edition	Nr of pages[3]	Nr of ill.[4]	% ill. of text
1868–75	1–7	536+	31	5.7
1878	8	629+	47	7.4
1892	9/92	912+	141	15.4
1899	9/99	1064+	268	25.1
1909–11	10	1920+	449+2	23.2
1924–39	10P	2731+	723+2	26.5
1939	11:3	358+	98+3	27.9
1940	11:4	358+	66+2	18.9
1939	11G:2	298+	122	40.9
1954	12:3	319+	212	66.4
1957	12:4	290+	220	75.8
1957	12G:2	314+	133	42.4

The first commonly used text book for all pupils in elementary school was "Folkskolans läsebok" (Reader for the elementary school). The first edition came out in 1868 and was followed by many new editions.

It was actually re-edited as recently as 1957 (Lindström, 1970). The development of illustrations in "Folkskolans läsebok" is shown in Table 8:1 above (excerpted from Lindström 1957).

A regular use of illustrations in text books began during the last decades of the 19th century. Advances in printing technique and photographic technique allowed illustrated books to be produced at a rather modest price. The illustrations were obviously a selling point for the publishers. The term "illustrated" occurs frequently in the titles of the book. The educational argument for illustrated books is, according to an editor's foreword, that they are more motivating to the children:

> "The illustrations are in several cases accompanied by longer and *more* informative legends than is usually the case. Many of the legends are furnished with literature references, as it has been shown, that pictures can stimulate curiosity more than the mere text."
>
> (Carlsson, F., Jordens länder och folk. Excerpt from the editor's foreword to the sixth edition, 1931).

In spite of the rather drastic changes in the appearance of text books during the 20th century, very little educational research has been carried out to describe this development. The study by Lindström related above is mainly an illustration of artistic aspects of the use of illustrations in "Folkskolans läsebok". Besides, "Folkskolans läsebok" is not representative of the development towards

[3] Text pages.
[4] The additional figures states the number of colour illustrations.

Table 8:2. The development in relative share of text and illustrations in two editions of a text book in geography (section on the climatological zones).

	1963 edition		1971 edition	
	Absolute area	% of tot. area	Absolute area	% of tot. area
Text	650 cm^2	49 %	761 cm^2	34 %
Pictures	348 cm^2	26 %	892 cm^2	40 %
Other illustrations than pictures	324 cm^2	25 %	582 cm^2	26 %
		100 %		100 %

"visualisation" of text books. The first reason is that it is more a collection of readings than a text book. The second reason is that the last edition appeared in 1957. Regular talking book production for blind pupils started after that year. If we want to assess the meaning and importance of visualisation for the visually handicapped students the development from about 1950 up till today is the most interesting.

There are however severe difficulties in finding a text book which has remained so relatively unchanged in content as "Folkskolans läsebok" as several curricular reforms have taken place since 1960.

A preliminary exploration in the study literature used in elementary schools did, however, reveal two books which have, in part, remained unchanged as far as subject matter is concerned. The consecutive editions of these books ought to show some trace of a "visualisation trend" in text books. The books, one in geography and the other in history, contained one passage each of which had been relatively unchanged with respect to subject matter from the beginning of the 1960's to the beginning of the 1970's.

Table 8:3. The development in relative share of text and illustrations in two editions of a text book in history (section on the world wars and the period between the wars).

	1965 edition		1971 edition	
	Absolute area	% of tot. area	Absolute area	% of tot. area
Text	3.152 cm^2	59 %	4.280 cm^2	38 %
Pictures	1.574 cm^2	30 %	6.006 cm^2	52 %
Other illustrations than pictures	597 cm^2	11 %	1.119 cm^2	10 %
		100 %		100 %

The volume of text and the volume of illustrations was calculated for each of the two passages in the two editions of the books. The result is shown in Tables 8:2 and 8:3.

The results show that there has been an increase in the use of illustrations in the books between the two editions. The increase is almost totally accounted for by an extensive use of pictures in the recent editions. Other types of illustrations (diagrams, charts, drawings) have not increased to any noticeable extent.

8.3 An empirical study of the use of illustrations in text books produced as talking books

The results of the pilot study related in the above section clearly support the notion of a visualisation trend in text book design. This is, however, not sufficient evidence to draw the conclusion that visualisation causes increased problems for the talking book producers and talking book readers. In order to get more detailed information about this special aspect of the problem, I made a study of figure descriptions in the books recorded as talking books since the beginning of talking book production.

By limiting the population studied to books actually produced as talking books the problem is somewhat changed. The aim is no longer to study the effects of *visualisation* independently of other changes causing increased use of illustrations in books, but rather changes in the use of illustrations that affect talking book producers. The effects of changes in choice of subject among blind students during this period will appear in the results for example. Such changes in the preference for different subjects will affect the work of the talking book producers. By keeping these "background variables" under control it will, however, be possible to identify and compare the effects of different factors, such as "changes in study preferences among the students" and "changes in the use of illustrations".

The population

Of the two talking book libraries in Sweden (see page 15) one is serving students at the university level, and is managed by the Swedish Association of the Blind. The other one has the responsibility for study literature to pupils who are integrated in elementary school and in high school. It is situated at the residential school for blind children in Sweden ("Tomtebodaskolan").[5] Both these libraries are included in the study. The population then will be defined as:

> "text books for visually handicapped pupils in comprehensive schools, upper secondary school and academic studies, recorded as talking books for the Association of the Blind or the library at the educational resource center at Tomtebodaskolan, which were published during the period 1950 to 1970".[6]

[5] This library is the same as the one called "RPH-SYN" in the introduction.
[6] 1950 is the earliest publishing year for any book produced as talking book.

This population contains about 2 900 books. The range of material at the Association of the Blind ("SRF") is described as follows in their own catalogue:

> "The emphasis is on literature for students studying social work, history, psychology, education, sociology, political science, phonetics and physiotherapy, in general up to Bachelor's degree, plus in law and language studies."

The range of material at the resource center at "Tomtebodaskolan" (RPH-SYN) includes text books for comprehensive school, upper secondary school and colleges of further education which have had blind pupils attending.

Sampling procedure

As a study of the total population of books would be too time consuming, some sort of representative sample of books to include in the study had to be made. As one of the points in the investigation was to trace the *development* of visualisation, and try to predict its future course, the original two strata were stratified once more, according to the year of publication of the books. The sizes of strata and samples are given in Table 8:4 below.

Table 8:4. Number of sampled talking books and the size of each corresponding stratum. Sizes of strata are given in parentheses under the value indicating sample.

	1951–1956	1956–1961	1961–1966	1966–1971	
RPH-SYN	5 (5)	10 57)	10 (88)	10 (412)	Σ35 (Σ562)
SRF	10 (64)	10 (121)	10 (≈800)	10 (≈1340)	Σ40 (Σ≈2325)
	Σ15 (Σ69)	Σ20 (Σ178)	Σ20 (Σ≈890)	Σ20 (Σ≈1750)	ΣΣ75 (ΣΣ≈2890)

Random samples were drawn from the books which were produced between the dates shown. Some books included in the sample contained so many figures that it was impossible to study all of them. In these cases figures were drawn by systematic sampling from the population of all figures in the book.

The first figure to be included in the sample was chosen at random among the first "n" figures in the book. Then every n:th figure was included in the sample. "n" was chosen according to the following formula:

"total number of figures in the book n" = 50.

The books included in the sample were classified according to subject matter. The result of this classification is shown in Table 8:5 below.

Table 8:5. Distribution of talking books on subject matter in the sample and in the population. The figures for the population are taken from the catalogues of the two libraries.

	Study literature library of the Association of the blind (SRF)		The national centre for educational aids for the visually handicapped (RPH-SYN)	
	Sample	Population	Sample	Population
Social science subjects (incl. geography)	20 (50 %)	1 003 (43 %)	10 (29 %)	183 (32 %)
Science	2 (5 %)	219 (9 %)	7 (20 %)	66 (12 %)
Humanities (incl. Law, excl. Language)	14 (35 %)	951 (41 %)	9 (26 %)	148 (26 %)
Language	4 (10 %)	159 (7 %)	9 (26 %)	171 (30 %)
	100 %	100 %	100 %	100 %

Variables registered

The recording of data from each book included in the study was carried out in two steps. First, the number of figures, the length in number of pages, publication year and subject area were registered. Second, the figures chosen were looked up in the talking book edition of the book, and the length of the description was recorded.

Results

As a first indication of "visualisation", the number of figures in the books was calculated. The result is shown in Figure 8:1 below. As can be seen in this histogram, the number of figures has increased considerably in the books from the Tomteboda talking book library. The producers serving comprehensive school and upper secondary school have thus been confronted with more graphical material than the producers for university level. The amount of graphical material has increased considerably during the period studied, at least in the "Tomteboda sample". The figures for the "Association of the Blind sample" show no clear trend. This however, does not necessarily mean that they have had to pay less attention to graphical material than their colleagues at the Tomteboda school. The figures from the two samples could be qualitatively different. The figures during the last periods from the library of the Association of the Blind might be more in-

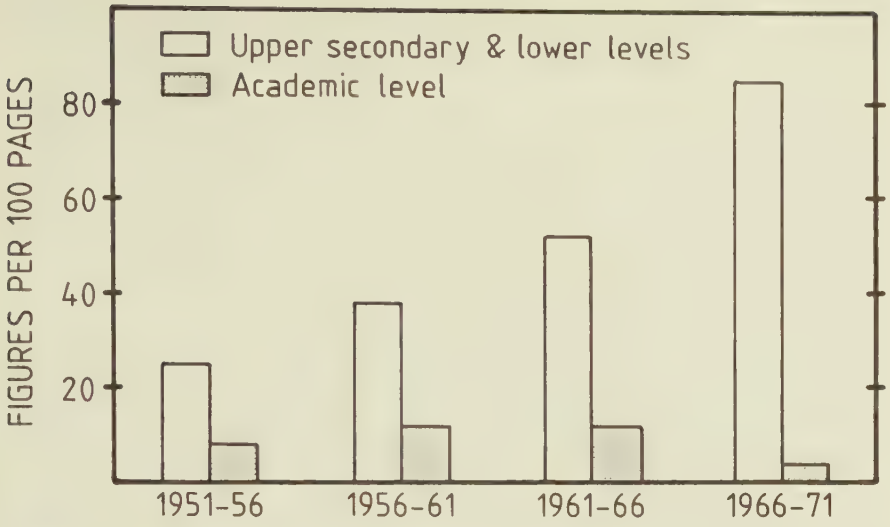


Figure 8:1. The development in amount of graphical material in text books produced as talking books for visually handicapped students. The results are shown separately for books produced for the academic level and books produced for upper secondary school and lower levels.

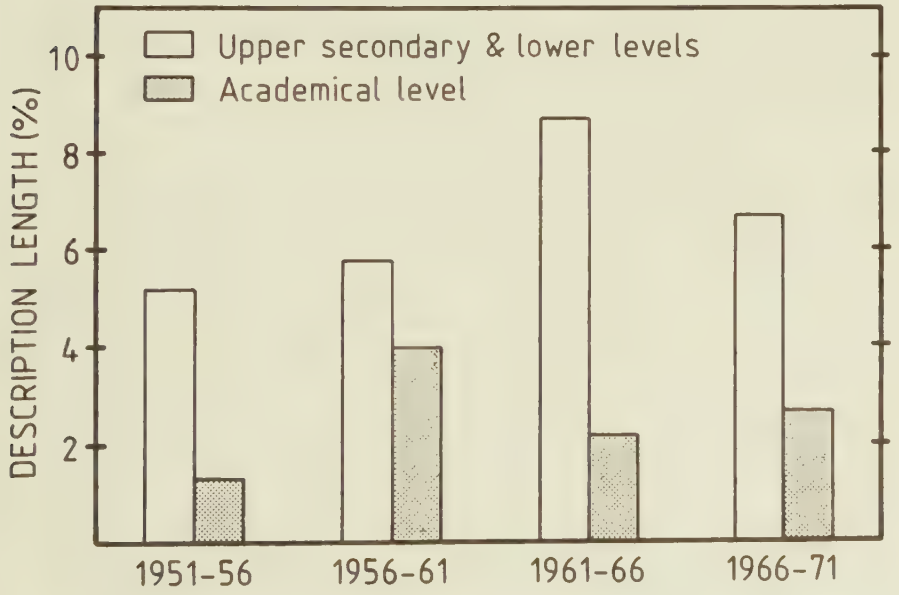


Figure 8:2. The share of figure descriptions (description length in % of total talking book length) in talking books from study libraries from 1951 to 1971. The result is shown separately for the two talking book libraries in Sweden.

formation rich than those from the first two periods. This would not show up in the number of figures in the books, but, presumably, in the description time of the figures.

To get a first apprehension of the average amount of information conveyed by each figure, the description length of the figure was related to total talking book length. The result of these calculations are shown in Figure 8:2.

The results indicate that many of the illustrations in books for the lower levels are not very information rich. The steep increase revealed in Figure 8:1 has disappeared. There is, however, still an increase in graphical information in the books during the period no matter how it is calculated.

For the academic books a small increase can also be seen. This increase did not appear in the data from Figure 8:1. It is, however, not very pronounced.

These results merely reflect the amount of time paid to graphical material in the recording studios. In the instructions to the narrators it is, however, stressed that figures must be duly prepared before the actual recording. Since the experiment reviewed in Chapter 5 led to recommendations to make figure descriptions shorter it is probable that this has affected the total amount of description time for the period 1966—1971. The length of the description is thus not a good measure of the problems caused by the figures. Besides, the kind of calculations we have made up till now does not say anything about the educational *value* and importance of the figures. It might well be that the narrators cannot cope with the most important and information rich figures, thus retreating to a description strategy common to all figures, which have a definite "ceiling" in length of description.

In Chapter 9 we will study the possibilities to get an estimation of the instructional value of the illustration material.

9. An analysis of the information conveyed by graphical information in text books

9.1 Review of relevant research

The key concepts of Conception I are "Information value" and "Psychological complexity". How much information do figures contain? What load do they exert on human mental capacity? Based on Shannon's theory of information measurement (Shannon & Weaver, 1949) many studies during the 1950's tried to relate the complexity of figures, as measured by Shannon's method, to different psychological variables. Discrimination (Rapport, 1957), subjective complexity judgments (Attneave, 1957) and pattern recognition (Fitts et al., 1956) were some of the variables studied. A thorough review of this research paradigm is given in Section 4.2. Most of these studies measured the information content in "nonsense" figures, and used the "bit-measure" to assess the *physical* complexity of the figures. There is still a lack of methods to assess the *psychological* complexity of a figure i.e. the amount of mental operations required to process a figure. An attempt to take psychological complexity of figures into account was made in the empirical study reviewed in Chapter 5. Wouldn't it be possible then, to use the same method to estimate the amount of information conveyed by figures in text books? This is unfortunately not possible. An empirical estimate of information value of different figures does not add up to a "gross information value". The "information value" of Information Theory is not applicable when *instructional* value of a figure is assessed. The question "To what extent do figures in text books create an educational handicap to the talking book reader?" cannot be reduced to an experimental question of theoretical information value. Furthermore, it is hardly possible to specify the instructional value of a figure, without taking into account in which context and with what aim the figure is used. An organisation chart for a company represents, for example, different information to a visitor who wants to know who is responsible for a certain function, than to a recently hired employee who is trying to learn the organisation of the company. The amount of information a figure represents is directly related to the purpose the perceiver wishes to achieve with the help of the figure. Ahlström (1969) remarks:

> "If we assume that a message has a certain course, that is, that it consists of signs appearing in a certain sequence, we can distinguish educational media which can never convey knowledge if they aren't contained in a sequence of other signs. Such media are pictures, graphs, physical models etc. They have only got a *reference function*. Other media also have a directive function, which controls the order different signs appear in. Among these are the text-book, self-instructing material

and, most of all, educational film, video tape (with content) and sound tape (with content). The teacher of course belongs to the educational media with double functions."

(page 145. My translation)

With the knowledge we have today concerning the human processing of pictorial information it is doubtful if we can achieve any theoretical principle for measuring information value of illustrations in text books. It is possible to measure their information value experimentally, as was demonstrated in Chapter 5, but these kind of methods are of little help when it comes to assessing the "visualisation" of text books.

It is, however, possible to get an estimation of visualisation in text books on a somewhat more crude scale than experiments would give. The mental load placed on the reader in processing a figure could perhaps be estimated in some kind of classificatory scheme. There have been many such schemes suggested for the classification of educational illustrations.

Knowlton (1966) remarks in an overview of this research field:

"Students of pictoral communication interested in classification schemes for pictures have generally stated their classifying rules in terms of the physical attributes of the vehicles involved. But if one is interested in the meanings of visual-iconic signs, and if the meanings are largely, if not totally, independent of the physical attributes of the sign vehicles involved, any such taxonomy that might emerge will be inadequate."

(page 174)

In the same article, Knowlton then suggests a classification system that makes distinctions between "realistic pictures", "analogical pictures" and "logical pictures". The following definitions of these three classes of figures are given:

Realistic picture:

". . . , a realistic visualiconic representation of some object in the visual world is a realistic picture *provided* that the communicators intent is to make reference to the type of object portrayed."

(Ibid page 176)

Analogical picture:

". . . , although such an illustration portrays objects in the visual world, these objects are portrayed only in order to show the nature of a structure or process: a process in which the portrayed objects 'participate' in manner common to the less familiar process (not so readily manifest) in the state of affairs that is of interest. This, then, is analogical representation."

(Ibid page 177)

Logical picture:

". . . , a visual representation where the elements are arbitrarily portrayed, while pattern and/or order of connection are isomorphic with the state of affairs represented."

(Ibid. page 178)

This system does not entirely build on the principle that classifications of instructional illustrations must be based on the meaning of the figures, in spite of the

opinions Knowlton puts forward in the quotation on page 68. "Realistic pictures" are defined by the intention of the author or editor, as are "analogue pictures". The definition of "logical pictures" on the other hand, is based on their design principle.

Knowlton's system is, however, not sufficient for an estimation of the role of visualisation in text books. None of the definitions specify the cognitive complexity of the educational objectives associated with the three classes. Besides, Knowlton considers all of his categories as "iconic", at the same time as he says that "logical pictures" can have ideas as referents. This must mean that Knowlton puts quite another meaning in the word "iconic" than the conventional one, which is derived from pictorial representation. (Ibid, page 175.)

Fleming (1967) describes a classification scheme based on the expected behavior of a pupil after having acquired the information in a figure, together with the physical design, "information level" and "verbal modifiers". Fleming has also calculated the correlation between the seventeen variables contained in the system. No vector analysis is made, however, so the seventeen basic variables make the system rather difficult to work with.

Anderson (1966) studied the effect of verbal versus pictorial representation on the connotations of a message. For this purpose a classification was made which divided pictures into simple/complex, and presentational/representational. "Presentational pictures", according to Anderson's definition, only presented themselves (i.e. a hexagon), while representational pictures were "pictures of something". This classification is not complete, and is perhaps not even intended to be complete. Illustrations of the type "map" or "diagram" do not fit into any of the categories in the scheme.

A comparison of the categories of the schemes proposed by Knowlton, Fleming and Anderson is given in Table 9:1 below.

As none of the classificatory schemes developed specially for illustrations in educational media seems to suit the present purposes, we have to proceed to classifications of models of knowledge in general. Ackoff (1962) relates a classification scheme for scientific models which is applicable to all models of knowledge and also estimates the information conveyed by model. The system also seems to be capable of classifying instructional illustrations according to the intent the textbook author has for them.

Ackoff distinguishes between "iconic", "analogue" and "symbolic" models, which represents an ascending scale of generality of description. As the symbolic models condense most knowledge, they also require most analysis to construct. Once they are constructed, they can be manipulated much easier than iconic or analogue models (ibid, pp. 108–110). In a research context, this gives symbolic models of knowledge a vast advantage compared to analgoue and iconic ones. This advantage is also apparent in educational settings, as symbolic models allow the pupil to elaborate the model actively in a number of ways. Iconic models just state facts concerning an object. Analogue models allow analysis of the

Table 9:1. Schemes for classification of illustrations in text books.

Originator	*Classes*	*Basis for classification*
Knowlton (1966)	1: *Realistic pictures* (objects portrayed to represent themselves) 2: *Analogical pictures* (the objects portrayed represent something else; "metaphors") 3: *Logical pictures* (The important aspect of the picture is the relation between objects. The objects themselves can be arbitrarily chosen)	The authors intention for the figures, and the principle of construction. The first principle refers to the two first classes, while the second refers to the last class.
Fleming (1967)	1: *Knowledge* (a) area (b) achroma 2: *Analysis* (a) framing (b) encoding style 3: *Synthesis* (b) shape (b) encoding medium 4: *Application/appreciation:* (a) Position (b) information level (c) elements (d) unification (e) chroma (f) sentences/non-sentences	Behavior expected from the reader who has been confronted with the figure
Anderson (1966)	1: *Representational figures* (pictures of something) (a) simple (b) complex 2: *Presentational figures* (present only themselves, i.e. a hexagon) (a) simple (b) complex	Type of object portrayed

phenomenon represented, while symbolic models in addition allow synthesis of new information concerning the object being studied, so that the pupil himself can relate it to other phenomena and acquire a structure of the object, process or system.

There are apparent parallels in the potential uses of Ackoff's categories of scientific models and Blooms (1969) classification of cognitive objectives in educational contexts. Bloom utilizes six main categories of "educational behaviours", constructed so that every additional class presupposes the previous ones. The classes are:

1: Knowledge
2: Comprehension
3: Application
4: Analysis
5: Synthesis
6: Evaluation

Of Ackoff's categories, "iconic models" can be inserted at level "1: Knowledge". Analogue models can be inserted at level "4: Analysis", and symbolic models can inserted at level "5: Synthesis".

Ackoff does not of course define his categories in terms of educational objectives as he aims at a general description of knowledge represented in scientific models. Ackoff's definitions describe the characteristics of models:

> "Iconic models are large- or small scale representations of states, objects or events. Because they represent the relevant properties of the real thing by those properties themselves, with only a transformation in scale, iconic models *look like* what they represent."
>
> (Ibid page 108)

> ". . . one property is used to represent another, and hence the necessity of a legend. In such cases the model is an *analogue*."
>
> (Ibid page 109)

> ". . . symbolic models in which the properties of the thing represented are expressed symbolically."
>
> (Ibid page 110)

These definitions are almost ostensive. A number of other aspects of Ackoff's categories could be used for definitional purposes. The following definitions stress the intentions with the models:

Iconic models refer to illustrations showing what something looks like. Examples of this category of illustrations are either pictures or drawing of objects.

Analogue models refer to illustrations demonstrating a certain aspect of phenomena, or comparing different phenomena from the same aspect. Examples are diagrams and maps.[1]

Symbolic models refer to illustrations demonstrating the structure of phenomena, i.e. an object's relation to other objects or the relation between subfunctions in a system. Organisations charts, flow-charts etc., are examples of illustrations in this category.

A practical test of these definitions was found to give a complete and unique classification of the illustrations in a couple of text books for the Swedish upper secondary school. Ackoff's classification scheme was thus chosen to describe the

[1] In one sense, maps are border-lines between iconic and analogue models. Knowlton's concept of "iconicity" (Knowlton, 1966) could apply here. When maps are used for educational purposes the distinction ought to be clear, however. As long as a legend is accompanying the map, the model is analogue; the author wants to stress a certain aspect of the mapped area.

development of graphical material in text books produced as talking books.

Before going into the empirical results of the study, some additional remarks concerning the assessment of development in graphical material in talking books must be made. Inkprint books can be made available to the visually handicapped either as a talking book or as a braille book. If there are many diagrams, special symbols etc, and little connected discourse, the braille format is often preferred. The criteria for the choice between talking book and braille book thus affect the development of graphical material in text books produced as talking books.

Another factor which can interfere with visualisation as the cause of changes in the use of graphic material is the student's choice of subject to study. It can be assumed that the reliance on graphics differs between text books of different subjects. This is crucial, especially at the university level. As the study preferences among the students change, the talking book producers' problems with graphical material are also changed.

To assess the information value of the increase in text book illustrations that were found in the frequency count related in Chapter 7, Ackoff's classification scheme was applied to this material. The results of this new description of the material are given in Section 9.2 below.

9.2 An empirical assessment of the information value of text book illustrations

The material studied in the frequency count of figures in talking books was classified into Ackoff's three categories: iconic, analogue and symbolic models.

As the reader might recall, the general result of the frequency count was that a steep increase in the number of figures occurred for the "Tomteboda sample", while the "SRF sample" did not show any conclusive trend. When the overall result is analysed into the three different categories of figures, pronounced differences in their development during the period studied appear. This is shown in Figures 9:1 and 9:2 for the "Tomteboda sample" (RPH-SYN) and the "SRF sample" respectively.

As can be seen in Figures 9:1 and 9:2, the development in frequency of illustrations is neither the same for the three categories of figures nor for the two libraries included in the study. The books from the "Tomteboda sample" show a still more marked increase in the number of iconic figures than is the case for the total material shown in Figure 8:1. Moreover, the frequency of analogue and symbolic figures is very low compared to the frequency of iconic figures, and it does not increase systematically during the period studied.

The material from the SRF library, on the other hand, does not show a corresponding increase in the frequency of iconic figures. On the contrary, the frequency decreased during the last period studied. As in the "Tomteboda" material, the frequency of analogue and symbolic figures is lower than the frequency of iconic figures, even if the trend is not as pronounced.

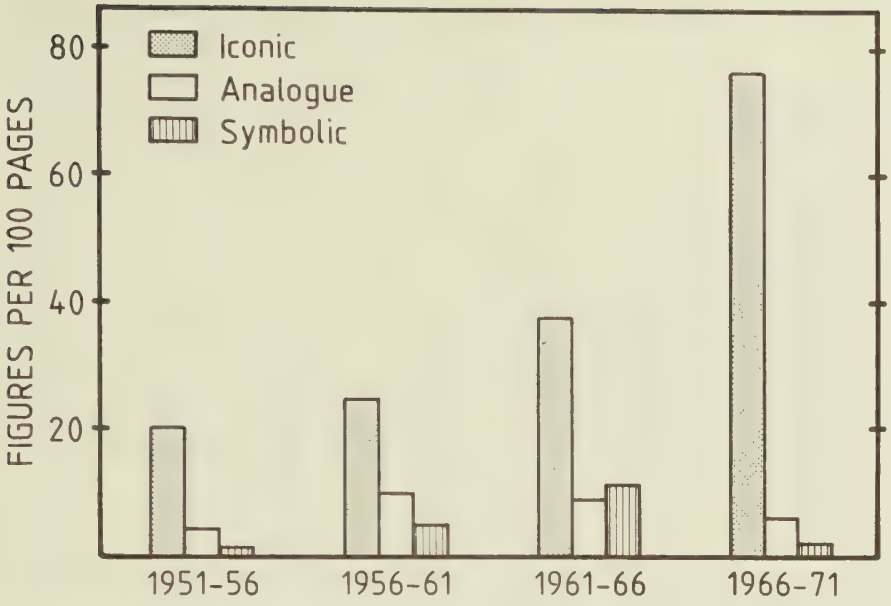


Figure 9:1. Figures in the samples of books from the national centre for educational aids to the visually handicapped (RPH-SYN) divided into iconic, analogue and symbolic figures.

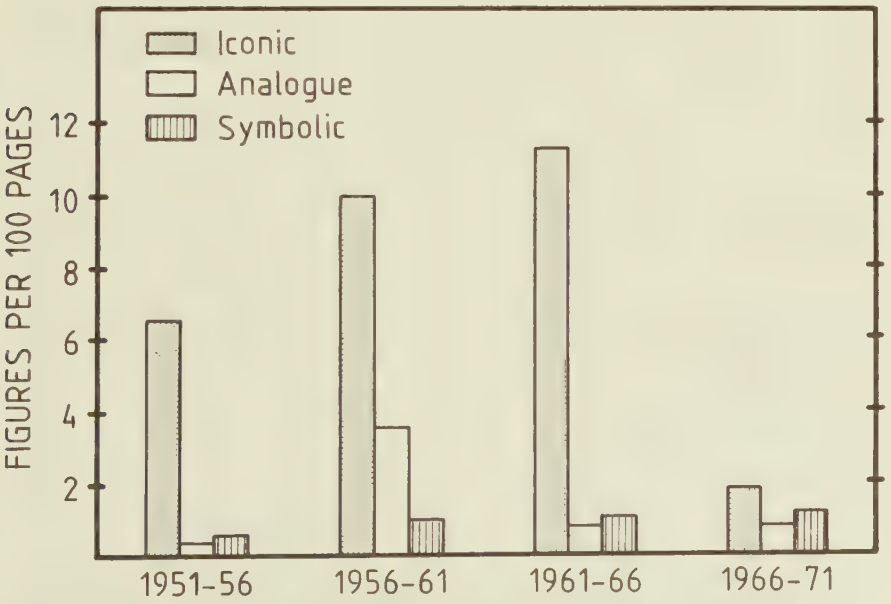


Figure 9:2. Figures in the samples of books from the study library of the Association of the Blind ("SRF sample") divided into iconic, analogue and symbolic figures.

The development of graphical material in books from the SRF library from 1961 to 1971 might have a very simple explanation, however. The decreased use of graphical material for the period 1966–1971 coincides with a steep increase in the number of students attending courses at the universities in Sweden. Production of printed educational material might not have been able to keep up with this development. A resulting widespread use of mimeographed material (without possibilities to reproduce pictures) might explain the development in the use of graphical material during the period.

The results of the analysis do not give any support to the notion of "visualisation of text books". This might however be due to insufficient validity of Ackoff's classification for the present purpose. It is, however, possible to get an estimate of the theoretical validity of the classification. Ackoff states that the symbolic models condense more information than analogue ones, which are superior to iconic ones in the same respect. If the length of figure-descriptions reflect the information content of figures, then the length of description ought to be positively correlated with this variable. The conceptual validity of Ackoff's classification for the present purposes was tested with a statistical test of mean-differences. The result supports the validity of using Ackoff's classification for the purposes of the present study. The result of the test is given in Table 9:2 below.

The results give strong support to the notion that iconic figures are the least information rich. The difference between analogue and symbolic figures is

Table 9:2. Mean and variance in description length for iconic, analogue and symbolic figures in the books in the studied sample. "n" = "number of books". Description length is given in seconds.

	RPH-SYN			SRF		
	$\bar{x}$	n	s	$\bar{x}$	n	s
1: Iconic figures	19.6	31	20.2	34.5	22	36.5
2: Analogue figures	37.0	17	19.5	134.3	14	150.0
3: Symbolic figures	63.1	14	55.9	118.9	11	105.6

t-tests of the differences between these means for the three categories in the two libraries gave the following results[2]:

RPH-SYN
$t_{(1-2)}=2.90$, $t_{(2-3)}=1.67$

SRF
$t_{(1-2)}=2.54$, $t_{(2-3)}>0$ (not in the hypothesised direction)

[2] The variance in some cases indicate that the distributions may be skewed. As a safety measure a median-test has therefore been carried out. The median-test did, however, give the same result as the t-test; there are significant differences in description length between iconic and analogue figures in the two stratas, but not between analogue and symbolic figures.

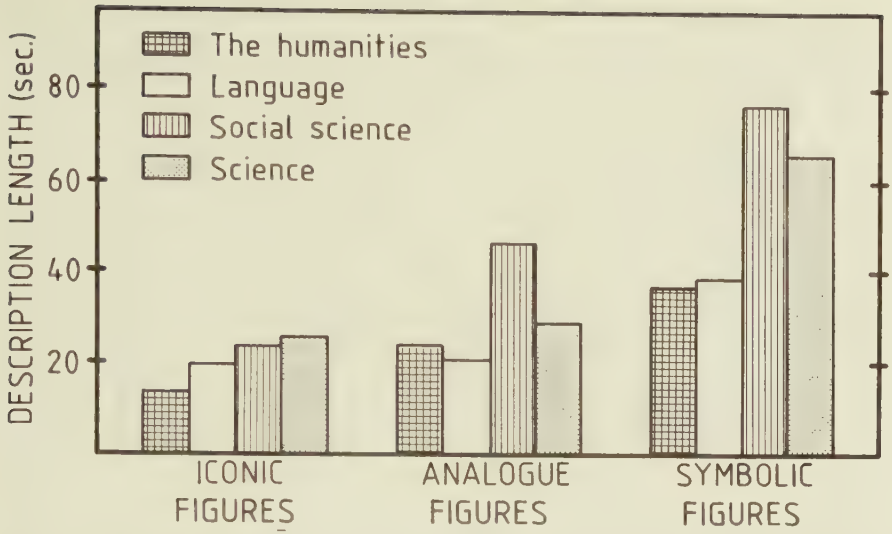


Figure 9:3. Average description time for iconic, analogue and symbolic figures in books from the humanities, language, social science and science. The calculations are based on 3 715 figures in 75 books.

somewhat less clear. The result is in the hypothesised direction in the "RPH-SYN" sample, but not in the "SRF"-sample. If the results are combined for the two libraries, the difference between analogue and symbolic figures also goes in the hypothesised direction.

The differences in description length between different subjects have also been calculated. Figure 9:3 shows that "subject" does not influence the basic relation between iconic, analogue and symbolic figures. The relation between description lengths for the three different categories are in the predicted direction. As in the material in total, the iconic figures have the shortest descriptions, followed by analogue, and longest, symbolic figures. The differences are somewhat more pronounced in social science books than in other fields.

In Figure 9:4 the figure description time as a percentage of the total recording time for the talking books during the four time periods (1951–56, 1956–61, 1961–66, 1966–71) is shown. If the results in Figure 9:4 are compared with the results from Figure 9:1 it can be seen that the increase in *number* of iconic figures in the material from "The Tomteboda sample" does not correspond to an increase in figure description *time* of the total recording time. For analogue and symbolic figures, on the other hand, the development in number of figures follows the development in recording time.

The results from Figure 9:4 are further elaborated in Table 9:3 below. Here the material is analysed with respect to subject matter and type of figure. Both the share of the total number of illustrations for the three figure categories and the figure-descriptions share of the total recording time have been calculated.

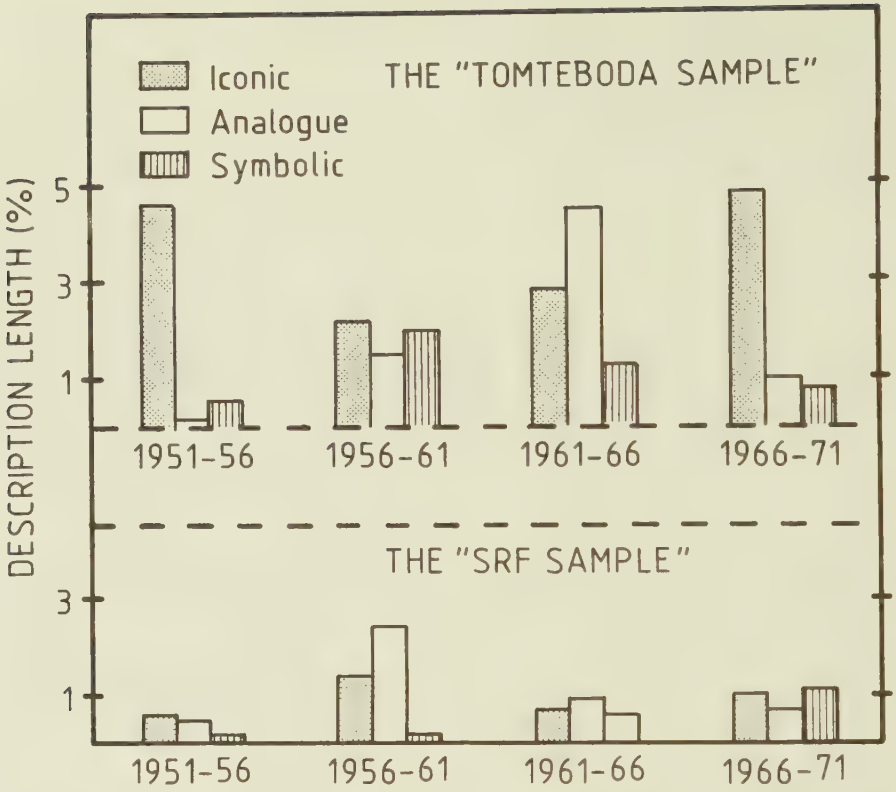


Figure 9:4. The share of figure descriptions (description length in % of the total length of the talking book) in talking books from 1951 to 1971. The material is divided into the categories "iconic", "analogue" and "symbolic" figures for the two libraries studied ("Tomteboda sample and SRF-sample").

Table 9:3. The share of iconic, analogue and symbolic figures of all illustrations in books from different subject areas. The share is given both as a percentage of number of figures and as a percentage of total description time.

	Iconic figures		Analogue figures		Symbolic figures	
	% of tot number	% of time	% of tot number	% of time	% of tot number	% of time
Books in social science	43	17	47	57	10	26
Books in science	84	78	3	4	13	18
Books in humanities	84	54	11	26	5	20
Language	94	75	3	9	3	16

Table 9:3 shows that iconic figures represent more than 80 % of all the figures in three of the 4 subject matter areas: "Science", the humanities and "Language". This domination remains for science literature also when the measure is "% of recording time". Social science differs from the other subject areas in that analogue figures dominate, both in percent of the total number of figures and in percent of recording time (47 and 57 % respectively). The share of recording time for iconic figures is also remarkably low compared to their share of the total number of figures in social science books (43 % and 17 % respectively).

From Figure 9:5 it can be seen that science books have much more information represented in iconic figures than the other subject areas. This can probably be explained with the special character of the iconic figures in science books. These figures often show organisms or anatomical details which are described in a special terminology. Analogue figures are typical for social science books. There are comparatively few figure descritpions in text books in the humanities and language.

The analysis so far has not shown any sign of a "visualisation of text books" which would constitute a severe handicap to the blind students. There is no systematic increase in the use of information rich figures. It could be possible, however, that the figures revealed by the talking book study are misleading. The editors could very well react to increased problems with graphical material with a tendency to prefer braille editions to talking book editions of a certain inkprint

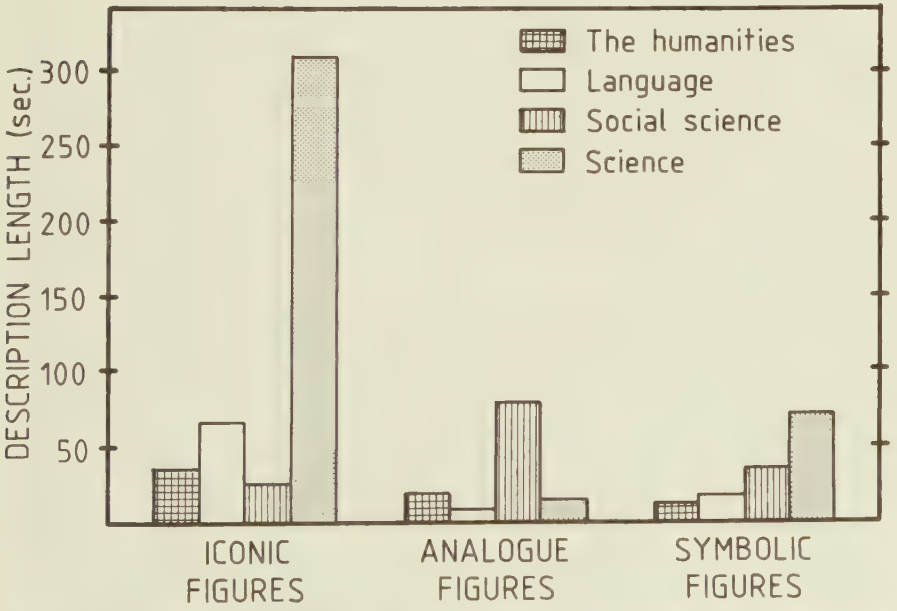


Figure 9:5. Seconds figure description per recorded hour for iconic, analogue and symbolic figures from books in the humanities, language, social science and science.

Table 9:4. Number and share of talking books and braille books during the time periods studied in the study literature libraries of the Association of the Blind and the National Centre for Educational Aids for the visually handicapped. (Sources: the registers of the libraries).

Publishing period (of inkprint book)	Association of the Blind		National centre (RPH-SYN)	
	Talking books	Braille	Talking books	Braille
1951–56	64 100 %	0 0 %	7 10 %	48 90 %
1956–61	121 98 %	3 2 %	57 31 %	127 69 %
1961–66	≈800 98 %	14 2 %	88 24 %	282 78 %
1966–71	≈1.340 94 %	78 6 %	412 40 %	627 60 %

book. Changes in the amount of really problematic graphical material could thus be occluded by a transition to braille book production. To explore this possibility, the share of braille- versus talking books in the two libraries was calculated for the period from 1950 to 1970. The result of this calculation is shown in Table 9:4.

It can be seen from Table 9:4 that the time-strata from "RPH-SYN" has a different composition during the last period as compared to the first period studied. For the period 1951–56 talking books constitute 10 % and braille books 90 % of the total amount of books produced. 1966–71 the corresponding figures are 40 % and 60 % respectively. This result does not give any support to the hypothesis that a transition to braille production could have occluded the effects of visualisation in study literature for the visually handicapped. On the contrary the material from the "Tomteboda sample" shows a marked increase in the volume of talking books.

The reliability of the classification into iconic, analogue and symbolic figures is of course crucial to all the results mentioned above which are based on Ackoff's scheme. As this scheme is a classification rather than a scaling, it is not possible to use any regular index of correlation. A remaining possibility is the "contingency coefficient". This index is described in detail by Jacobson (1972). As the theoretical maximum value of this index in a 3 x 3 matrix is only .816., it is however not very suitable as a measure of reliability. It is, however, possible to get a conception of the reliability of the classification from Table 9:5 below.

As can be seen from Table 9:5 there is only 8 % of the classifications which differ between the two reviewers. As one of the classifications at the same time served as training in the use of the system, the figure 8 % also contains obvious

Table 9:5. Confusion matrix for the two classifications of 133 figures made by two independent reviewers.

	Judgement No 2:			
	Iconic figures	Analogue figures	Symbolic figures	Total
Judgement No 1:				
Iconic figures	88	4	4	96
Analogue figures	0	23	3	26
Symbolic figures	0	0	11	133
Total	88	27	18	133

mistakes. 8 % can be considered an upper limit for the reliability-deficiencies of the classification scheme.

9.3 Discussion of the results of the empirical study

The aim of the study reviewed above was to describe the use of illustrations in books produced as talking books, and, with this description as a basis, try to make a judgement concerning the development of the use of illustrations in text books and what effects this might have for the readers and producers of talking books.

The description of the use of illustrations and factors affecting this use can be condensed under 4 points:

1) The relative frequency of study literature in the libraries.
2) The frequency of illustrations in the books that are going to be produced as talking books.
3) Complexity of the figures in books that are going to be produced as talking books.
4) The distribution of books produced as talking books and books produced in braille.

The implications of the results which have been related above are discussed under these headings below:

The first point is only relevant for the library at SRF, as the library at RPH-SYN is exclusively engaged in the production of study literature. In the SRF sample a doubling of the relative frequency of study literature has occurred from 1963 to 1973. The development has not continued to increase in this way after 1973, so the problems due to this factor will presumably not continue to increase as it has done earlier during the 1970's.

Concerning the second point there is a strong increase in frequency of figures for the material from the RPH-SYN library, but no corresponding increase for the material from the SRF library. The borrowers and producers of talking books at

RPH-SYN will presumably get increased trouble with graphical material due to this compared to the situation today.

The analysis relevant to the third point shows that the steep increase in frequency of figures in text books is, by and large, due to an increase in the *least* information rich figures. The difficulties with graphical material will increase relatively slowly as long as this situation endures.

Concerning the fourth point, there is a tendency towards an increased share for talking books as compared to braille books for the RPH-SYN library. The SRF library shows a weak tendency towards more braille books.

There is hardly reason to believe that just the increased share of talking books will create increased problems with figures for readers and producers. Seen against the background that the factor causing the increased share of talking books might be a change in subject preference among the students, the situation can still be problematic. A development towards more social science literature and less language could increase the problems. The social science books have a more sophisticated use of figures than the language books. More information rich figures are used. More than 80 % of the illustrations in books in social science are analogue or symbolic, requiring careful editing and long verbal descriptions. The corresponding figures for books in language is only 6 %.

In conclusion it can be said that no "visualisation", with figures replacing text, seems to be happening.

Some comments on the problems associated with generalising from the empirical study are necessary. The aim of the present study was to describe and make a prognosis for the use of illustrations in text books produced as talking books. It is thus essential that the sampling method does not distort the picture of the actual use of illustrations in the studied samples. Whether such a distortion occurs depends to a certain extent on how the samples are defined. If they are said to include books included in the catalogues from the study literature libraries for the blind the sampling is presumably correct. If, on the other hand, samples are defined as text books used by visually handicapped students during the periods investigated, the representativity of the results can be doubted. There were very few talking books produced in Sweden during the 1950es. Some books from this period in the sample could have been produced later. Moreover, not all talking books produced are included in the catalogues of the respective study libraries. Many books which have been damaged or replaced by others have also been omitted from the catalogue. It has not been possible to get any information on these matters, so it is difficult to estimate the distortion that might have occurred due to this.

A possible way out of this difficulty might have been to investigate a shorter period, say from 1965. Such a method could, however, result in other types of distortions of the results. The long-term trend could very well have been hidden behind random changes from year to year. It is thus not possible to get rid of these problems of generalisation altogether.

9.4 Practical outcomes of Conception II

Conception II aimed to find the answer to the question "How essential is graphical information in text books?", or, formulated another way: "How much information is conveyed by graphical information? Furthermore, how valuable is this information to the reader?"

The empirical studies of text books in the talking book libraries indicate that the development towards "visualised" text books has not meant that an increased share of the information in text books is conveyed graphically. There has been an increased use of illustrations in text books, but no substantial increase in the information conveyed by them.

At the same time the studies of text books in the talking books libraries showed that there were figures which conveyed very much and very important information in text books. It follows from the results of Conception I that these figures cannot be described verbally. The readers of talking books will not understand very much of descriptions which are sufficiently long to cover the content of the figure. Other means of representing these figures have to be found if the information in them is not to be lost for the visually handicapped student.

Another factor that makes verbal descriptions unsuitable as the only means of representing graphical information in talking books is the *function* of the figure in the text. Quite aside from it's information value, figures can function differently in different discourse contexts. The same iconic figure can act as material for exercises in one context, as well as animation of the text in another. A verbal description is not recomendable in the firts case whereas a verbal description is fully acceptable in the second case.

Such considerations have not been dealt with previously. The first conception dealt with the amount of information in a figure or figure description, while the second dealt with the complexity of the instructional objective that is associated with the figure. The function of the figure is not included in the "Ackoff-scheme". Whether a figure is "iconic", "analogue" or "symbolic" depends on the mental complexity that is required in the acquisition of the figure, not on the function of the figure. The theoretical conclusions of the studies therefore have to be integrated with practical considerations to be of any value to the talking book producers and readers. Such a comprehensive picture of the factors to be taken into account by the editors and narrators of talking books was presented in a final report on editing problems in talking book production released by the PUSS project in 1974 (Trowald, 1974). Some of the main conclusions as regards the treatment of graphical material is presented below.

The first consideration an editor ought to make when he is confronted with a figure in a book is whether the figure could be left out or not. A figure filling a mere decorative function in the inkprint book might very well be left out in the talking book. Many iconic figures can be left out,[3] but not analogue or symbolic

[3] Provided that the figure does not contain information needed in exercises etc (cf Figure 9:6).

figures. The loss of information caused by leaving out an iconic figure is often marginal compared to the information loss caused by a left out analogue or symbolic figure. It could also be the case that the text conveys the same information as the figure does. An additional description would be superfluous in such cases.

Analogue and symbolic figures can, however, give rise to another problem: The narrator doesn't know the subject well enough to understand what the author wants to say with a figure. One possibility in this case is to get a written description of the figure from an expert, and records this description.[4]

Still another possibility is to refer it to a personal assistant. This can be a practical alternative for very complex figures, which might be the basis for a whole chapter in the book. These figures can also be represented in relief form. The possibility of representing figures in relief form is, however, not commonly used. The production of raised-line material is rather time consuming. Moreover, there are no commonly accepted conventions concerning symbols in relief-graphs. It is also dangerous to overestimate the potentials of relief representation. The tactile reading of a raised line graph is much more difficult than the visual reading of an "inkprint" graph. The initial overview that is acquired rather easily when the figure is inspected visually is a rather complicated matter when it comes to tactile reading. Isolated parts of the figure are sequentially and gradually built up into a whole when the figure is read off tactually. There is a saying that reading a raised line map tactually is like reading a wall map visually with a magnifying glass. A raised line figure can thus not be considered a simple equivalent alternative to the inkprint figure.

The difficulties and drawbacks with relief representation of figures must, however, not be interpreted as advice to refrain from this form of representation. On the contrary, tactile figures can be a very good complement to the talking book. For practical and economical reasons they are, however, often left out in talking book production. If just one person is interested in the book, and the need is fairly urgent, it is too expensive and time consuming to make a relief figure. In this case, a personal assistant can be a good alternative.

The theoretical and practical conclusions of Conception II are summarised in a "decision tree" in Figure 9:6 below. The decision tree shows the considerations which the editor ought to make, when he chooses between different ways of representing graphical material in a talking book. It should be stressed however, that special circumstances or special wishes expressed by the student must be considered first. The decision scheme can, however, be helpful if the editor must choose between several alternatives.

When the narrator gets the book it is already edited. The editor has decided how a certain figure should be represented, or if it is to be left out. The editor has, however, seldom the opportunity to read the book as carefully as the narrator. Thus it is possible that the narrator can come to different conclusions than the

[4] This is often a rather time-consuming method. If the narrator can get an understanding of the figure personally this is to be recommended.

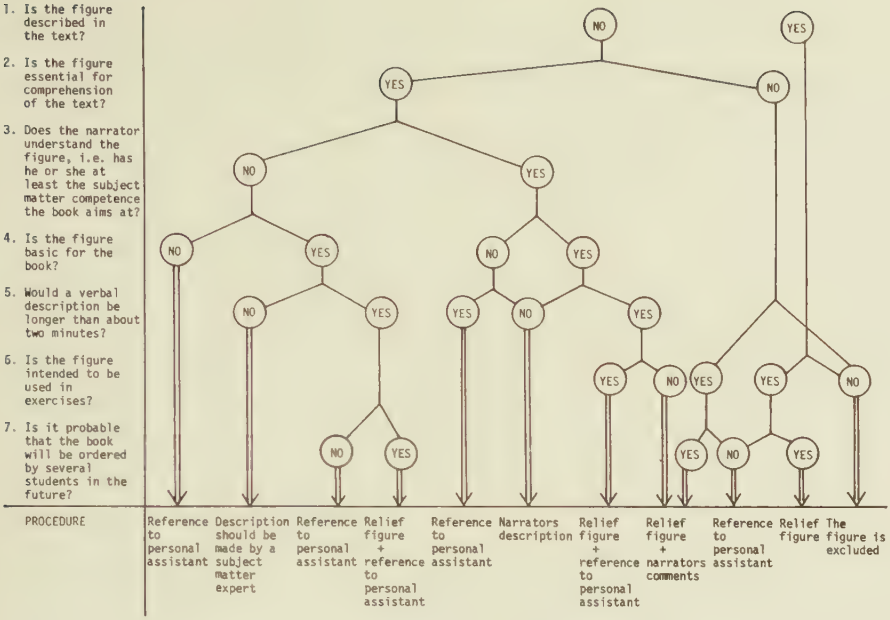

1. Is the figure described in the text?
2. Is the figure essential for comprehension of the text?
3. Does the narrator understand the figure, i.e. has he or she at least the subject matter competence the book aims at?
4. Is the figure basic for the book?
5. Would a verbal description be longer than about two minutes?
6. Is the figure intended to be used in exercises?
7. Is it probable that the book will be ordered by several students in the future?
PROCEDURE
Reference to personal assistant
Description should be made by a subject matter expert
Reference to personal assistant
Relief figure + reference to personal assistant
Reference to personal assistant
Narrators description
Relief figure + reference to personal assistant
Relief figure + narrators comments
Reference to personal assistant
Relief figure
The figure is excluded
YES
NO

Figure 9:6. Decision tree for the choice of form of representation of graphical material in talking books.

editor. The editor, for example, might have left out a figure which the narrator finds very important for the comprehension of the text that follows. The figure can also be more complicated to describe than the editor imagined when he left it to the narrator to describe. It is also possible that the narrator chooses to insert the description of a figure at another position in the text than the one which the editor choose.

After having made these considerations, the narrator should make a plan for the description of the individual figures.

There is no use in trying to make an unprepared description in the studio. At best, such a method means considerable repetitions and disturbances in the recording. At worst, the narrator just forces through the description, ending up with a figure description which is all nonsense to the reader.

The plan should not be a written description—a relaxed spoken discourse is to be preferred. A couple of notes listing the main features of the figures should rather be the aim. It is important that the description always starts with the objective of the figure. The first passage of a description is thus: "Figure 1 shows (explains). . .".

The first task for the narrator is thus to make the authors intent with the figure clear to himself. If he finds this impossible it is no use in trying to describe it.

The plan should be built up around the aim with the figure. The actual appearance of the figure is seldom important.

CONCEPTION III
An ergonomic Approach to text design and composition

Foto: Peko-Bild, Stockholm.

10. What does graphical information contribute?

10.1 A follow up study

The work with figure descriptions in talking books reviewed in Conception I and II took place during 1970–1972. The final report on talking book production appeared in 1974. During the three years since then it has been used as introductory material for new talking books editors and narrators. It has also been used as supplementary material for those who have already been hired. The report thus ought to have had some impact on the practical work with graphical material in talking books.

To study if the recommendations concerning graphical information have been of any value to the talking book producers, a follow up study was made in 1977. Among the talking books produced during 74/75 to 76/77 20 from each of the two libraries supplying literature to visually handicapped students were included in the sample to be studied. These forty books were drawn at random from the total population of talking books produced during the three years.

All the figures in the books were classified as iconic, analogue or symbolic. The editors remarks in the inkprint edition were also recorded into the categories from Figure 9:6.

The results of this cross classification are shown in Table 10:1 for the sample from the SRF library and in Table 10:2 for the sample from the RPH-SYN library.

Table 10:1. The editors treatment of graphical information in books recorded as talking books. Figures from the SRF sample.

	Measure recommended by the editor:							
Type of figure:	Student referred to pers. ass.	Descr. by subject matter exp.	Relief-repr.	Descr. by the narrator	Short comments by the narrator	Figure excluded	Descr. on suppl. tape	Not ident., no rec.
Iconic figure	0	0	0	0	0	56 (90 %)	0	6 (10 %)
Analogue figure	6 (15 %)	0	0	5 (13 %)	8 (21 %)	11 (28 %)	0	9 (23 %)
Symbolic figure	0	0	0	27 (40 %)	4 (6 %)	21 (31 %)	4 (6 %)	11 (16 %)

Table 10:2. The editors treatment of graphical information in books recorded as talking books. Figures from the RPH-SYN sample.

Type of figure:	Measure recommended by the editor: Student referred to pers. ass.	Descr. by subject matter exp	Relief repr.	Descr. by the narrator	Short comments by the narrator	Figure excluded	Descr. on suppl. tape	Not identified, no rec. made
Iconic figure	7 (0.5 %)	0	0	17 (1 %)	248 (13 %)	1.232 (64%)	0	434 (22 %)
Analogue figure	18 (9 %)	0	0	26 (12 %)	72 (34 %)	72 (34 %)	0	25 (12 %)
Symbolic figure	0	0	0	11 (6 %)	68 (34 %)	103 (52 %)	0	18 (9 %)

It can be seen from Tables 10:1 and 10:2 that more than 50 % of the figures in a text book produced as talking book are excluded. This is in line with the recommendations put forward in the final report on talking book recording (Trowald, 1974) for iconic figures, but not for analogue and symbolic figures. 90 % of the iconic figures in the SRF sample, and almost 2/3 of the iconic figures in the RPH-SYN sample are left out. According to the theoretical discussion in Chapter 9 concerning the amount of information conveyed by different categories of figures, iconic figures do not contribute very much information. The fact that they are left out is consistent with the theoretical guidelines. The treatment of figures belonging to the other two categories is not, however, in line with the theoretical recommendations. Most of them are excluded, and the majority of the remaining ones are just commented upon. Exclusion rates of between 28 and 52 % for these categories of figures implies heavy information losses for the talking book reader. On the other hand, the editor's professional judgement on which figures to exclude ought to be reliable. A further analysis of the context of some of the figures left out might explain the findings.

10.2 The context of graphical information in text books—some examples

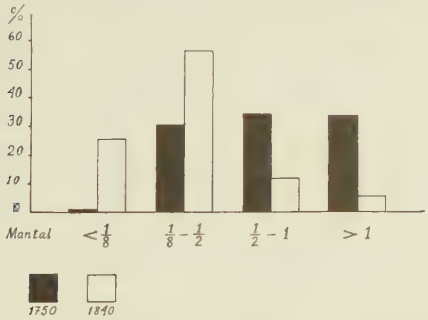
The seemingly contradictory findings in the retrospective study and in the study of information value of figures can perhaps be explained with a reference to Figure 9:6 on page 107. The first question the editor has to put when he is confronted with a figure is whether it is described in the text or not. If it is described already, it is argued that one additional description is superfluous. There is just one catch in this line of reasoning: why are the figures here at all if they are accompanied by a

verbal description saying exactly the same thing as the figure? Of what use is the figure to the sighted reader?

We will study a couple of examples of excluded analogue and symbolic figures from the follow up study to see if it is justified to exclude them.

The first examples are taken from a text book in history for upper secondary school[1]:

I Sverige köpte de flesta kronobönderna sina arrendegårdar, och genom riksdagsbeslut 1789 och 1809 fick bönderna också rätt att köpa frälsejord. I Danmark hade bönderna i århundraden varit livegna: först "vornedskabet" och sedan "stavnsbåndet", som var de danska typerna av livegenskap (del I, s. 26). År 1788, året före den franska revolutionen, upphävdes emellertid stavnsbåndet. Därefter friköptes många gårdar, så att vid mitten av 1800-talet 60 procent av de danska arrendegårdarna övergått till självägande bönder. I Sverige ägde då bönderna omkring 60 procent av den totala jordarealen, en fördubbling sedan 1720.



Bondgårdarna var i regel små enheter. Stapeldiagrammet belyser hur hemman och hemmansdelar i södra och mellersta Sverige grupperade sig efter mantal år 1750 och hundra år senare. Tendensen är entydig. Den liksom så mycket annat i näringslivet under detta skede förklaras av det enorma tryck som den snabba folkökningen utövade.

Skifte och hemmansklyvning gav mera mat åt allt fler, men det visade sig dock omöjligt för den egentliga bondeklassen att suga upp befolkningsöverskottet, trots att man nyodlade, klöv hemman och förbättrade brukningsmetoderna. Det fanns inte heller en utbyggd industri som kunde ge arbetstillfällen. Överskottet hamnade därför i jordbrukets underklasser som ett jordbruksproletariat.

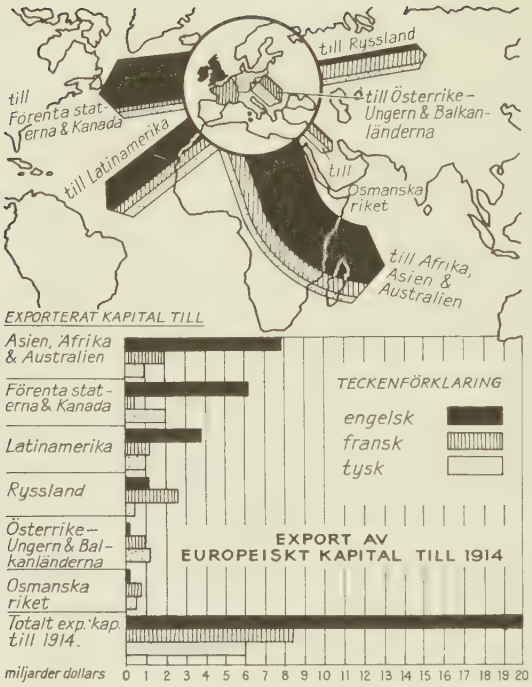
This histogram odds detailed information to the statements in the text. It's main function seems to be to verify what is said in the text. The fact that it has been excluded by the editor does, however, not cause any difficulties for the reader. It is perfectly possible to read the discourse without the figure.

The next example is taken from a paragraph on the causes of imperialism[2]:

[1] The Swedish text treats the development from large agricultural estates owned by a few wealthy men to smaller units owned by many independent farmers. This development is explained by the steep increase in population during the period 1750—1850.

The figure shows the same development in graphical form. From: Borg et al., *Historia 2 ET*, p 104. Läromedelsförlagen 1968. Sid 112.

[2] The text is about the causes of imperialism. Imperialistic trends during the period up to the First World War is explained by a capital excess created by industrialisation, and giving the highest return rates when invested in the colonies. The two figures give detailed evidence for this these. (Ibid., p 142).



Skissen ovan visar kapitalexporten från England, Tyskland och Frankrike fram till 1914.

Kapitalströmmarna från Industri-Europas tre ekonomiska stormakter, England, Frankrike och Tyskland, var betydande. Skissen visar att Europa exporterade 35 miljarder dollar fram till första världskriget. Industrialismen gav överskottskapital. Tidigare hade detta huvudsakligen använts till att bygga upp industrin i Europa och i Nordamerika. Från och med slutet av 1800-talet gick emellertid betydande kapital till kolonierna. Att det i Europa fanns överskottskapital att investera där det gav bäst avkastning kan därför sägas vara en av orsakerna till imperialismen. Skissen visar emellertid också att endast omkring 1/3 av kapitalexporten gick till Asien, Afrika och Australien, dvs. de koloniala världsdelarna. En stor fransk kapitalexport gick till Ryssland, som alltså inte hade något överskottskapital men ändå i storleksordning var den tredje kolonialmakten näst efter England och Frankrike. Att överskottskapitalet orsakade imperialismen kan därför inte vara hela sanningen.

Om vi i stället vidgar perspektivet till att omfatta det industrialiserade samhället med dess importbehov och dess krav på nya marknader både för sitt överskottskapital och för sina industriprodukter, fångar vi mera av imperialismens förutsättningar. Asien och Afrika kunde erbjuda viktiga råvaror, såsom bomull, silke, gummi, olja, guld, tenn och andra sällsynta mineralier.

När industrialismen slagit igenom i Europa och Nordamerika och stora investeringar redan gjorts där i järnvägar, fabriksanlägg-

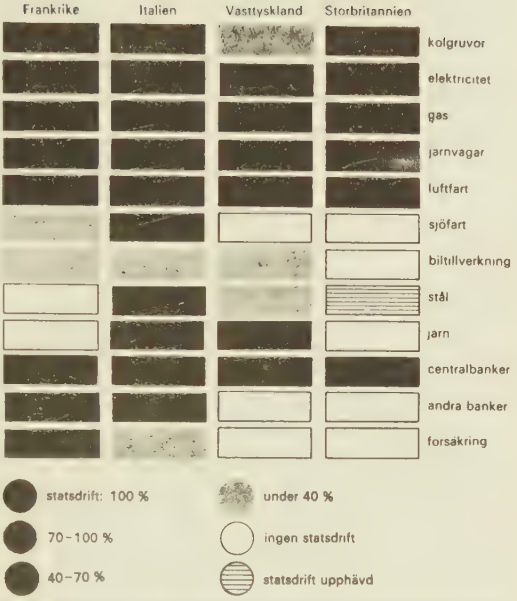
The figure is not necessary for the comprehension of the paragraph. The talking book reader will understand the point without the figure, but the sighted reader gets much more detailed information on the subject.

The third example from the textbook in history illustrates a section on "the socialist economy". It verifies the argument that public enterprise is very common in capitalist economies, and gives detailed information on conditions in this respect in four european capitalist countries[3]:

[3] The text's main point is that "socialist economy" and "public enterprise" are two distinct phenomena. This is illustrated by the share of public ownership in different sectors of the economy in four European countries. (Ibid., p 241).

Av figuren s. 241 framgår att företag i samhällets ägo inte är något som enbart förekommer i socialistiska stater. I ett kapitalistiskt land som USA drivs posten, vägbyggen, en stor del av skolväsendet och bostadsbyggandet i samhällets regi, liksom Tennessee Valley Authority. Andra områden *regleras* av staten. Telefon och järnvägar exempelvis får sina taxor reglerade av staten. På prispolitiken kan staten genom sin starka ställning som köpare öva inflytande. Ingripande i form av tullar och subventioner (exempelvis till jordbruket) spelar stor roll. Statens ansvar för att via budgeten och penningpolitiken reglera den samlade efterfrågan är allmänt erkänd. Den amerikanska statens satsning på forskning och utveckling – 21 miljarder dollars 1963/64 mot Västeuropas 6 miljarder – är en nyckelfaktor i fråga om den amerikanska industrins framväxt.

I Västeuropa är i regel, som framgår av figuren en betydligt större del av näringslivet samhällsägt. Stora koncerner som National Coal Board (Europas största kolindustri), British Steel Corporation (världens näst största stålkoncern), Renaults bilfabriker i Frankrike, Alfa Romeo i Italien, LKAB i Sverige är i statlig ägo. Central planering spelar stor roll. Frankrike har här gått i täten genom fyraårsplaner för näringslivet sedan 1946, utarbetade av Commisariat Général au Plan.



Statligt ägande inom olika sektorer av ekonomin i fyra europeiska länder.

The text can be understood without the figure, but the figure gives much more detailed information on the subject than the text does.

There are two more examples of analogue figures which have been left out in the talking book edition of this book. They are both political maps, and contribute very little additional information to the text. The average sighted reader presumably does not pay very much attention to them.

The next figure is taken from a book produced as course literature for the academic level. It gives the relation between the frequency of a soundwave and its intensity in decibels measured by three different indices[4]:

[4] The text describes three filters for measuring. The figure shows their respective sensitivities to different sound frequencies. From: Gerhardsson, G. *Buller*, p. 64. Bonniers 1973.

Ljudet vägs av örat. För att efterlikna detta förlopp har elektriska dämpningsfilter konstruerats, som filtrerar bort en del av ljudet så att mätarutslaget bättre svarar mot hörselintrycket. IEC har standardiserat tre filter: (A), (B) och

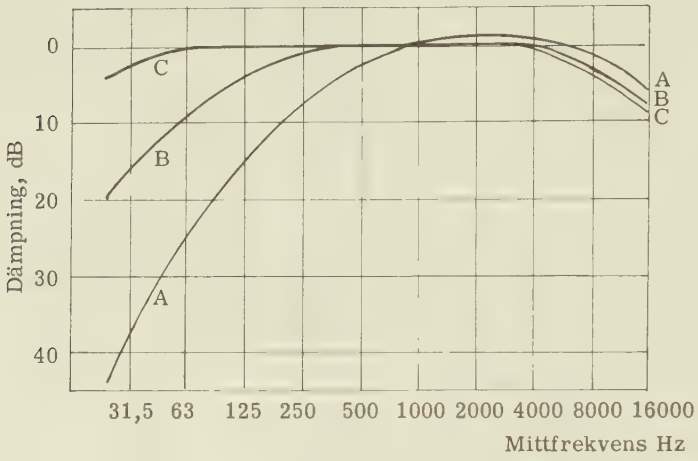


Bild 5:10 Vägningsfilter enligt IEC-publ. 123 och 179

(C) (bild 5:10). (B) filtret har numera liten användning. Genom att samtidigt mäta med både dB(A) och dB(C) filter kan man skaffa sig en uppfattning om hur rikt bullret är på lågfrekvent ljud. Är skillnaden mellan avläst dB(C) och dB(A) mindre än 2 dB är bullret ganska fattigt på låga frekvenser, överstiger den 10 dB kan man räkna med att bullret till dominerande del är lågfrekvent (jfr tab. 8:2 s. 118).

Vissa mätare är utrustade med ett dB(D) filter som förstärker en viss del av det högfrekventa ljudet. De används främst för flygbuller.

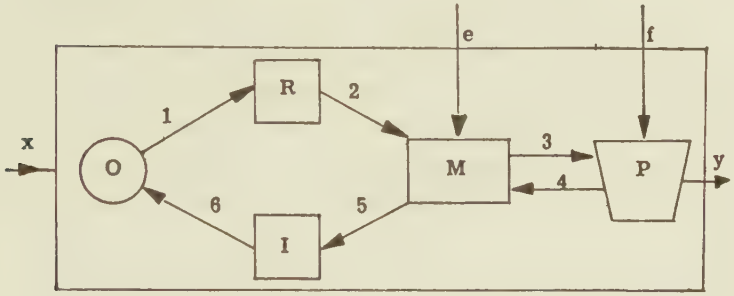
The figure gives information which is not given elsewhere in the text. The information conveyed by the figure is lost for the talking book reader, as the figure is left out.

The third book provides some examples from academic course literature in the behavioral sciences. It is called "Man, work, vocation" and gives an introduction to theories in occupational psychology, vocational guidance, labour market theory etc. Books on behavioural science often contain a lot of so called "box models", and this one is no exception. We will give some examples of figures which have been excluded by the editor[5]:

[5] The text treats a method of job description based on flow chart representation. The first diagram shows an automated work task and the second one a manual task. The third diagram shows a common description of both manual and automated processes. From: Waern, K-G. Människan, Arbetet, Yrket, p. 15—17. Bonniers 1971.

I litteraturen på det här området stöter man då och då på diagram som mer eller mindre liknar det nedanstående. Det beskriver ett människa-maskin-system som tillverkar en viss produkt. "Lådorna" eller "burkarna" i diagrammet betecknar systemets komponenter och pilarna relationerna. (De sifferbetecknade pilarna är som synes relationerna inom systemet och de pilar som är betecknade med små bokstäver anger systemets relationer med sin omvärld.)

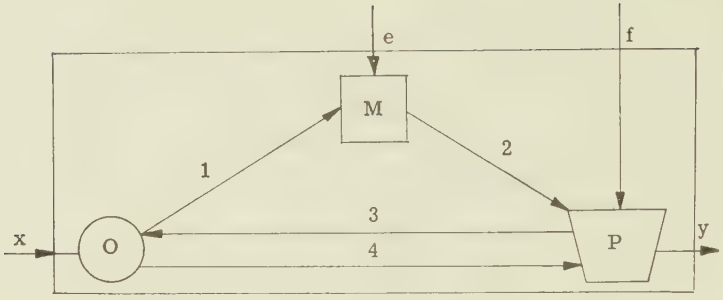
Diagram 1



Komponenten O är "operatören" som via reglagen R påverkar maskinen M. Denna påverkar i sin tur produkten, P, och känner samtidigt av (pil 4) resultatet av bearbetningen. Bearbetningsresultatet meddelar maskinen sedan via instrumenten I tillbaka till operatören. Med ledning av de data som O får från instrumentavläsningen kan han modifiera sina manövrer med reglagen R, osv. *Inflödet* till det här systemet består av tre saker: pilen x som vi för enkelhetens skull kan säga utgörs av order eller instruktioner till O (i verkligheten måste man beakta en hel del andra "inputs" också) samt av e och f som är energitillflöde till maskinen respektive tillförsel av råmaterial för produkttillverkningen. *Utflödet* från systemet (pilen y) kan vi säga utgörs av den färdiga produktens egenskaper.

Det föregående diagrammet kan sägas beskriva tillverkning i en helautomatisk process, där operatören inte lägger hand vid själva produkten. Försöker vi göra ett diagram över en mera hantverksbetonad tillverkning kan det kanske se ut så här:

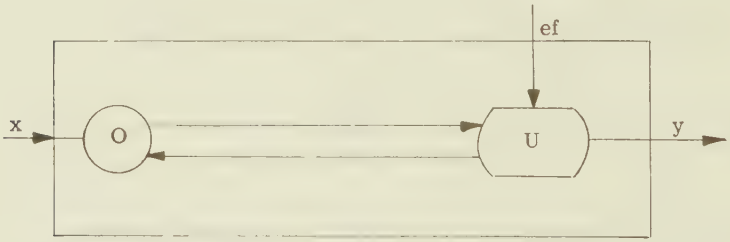
Diagram 2



I det här diagrammet kan vi anta att "maskinen" utgörs av något slags verktyg, det må vara en motorsåg, en hyvel, en skrivmaskin eller något annat. (Det behöver inte röra sig om bara ett enda verktyg heller utan kan vara en hel uppsättning.) Operatören hanterar också på ett eller annat sätt själva produkten.

Diagrammen 1 och 2 ser något olika ut, men de kan reduceras till en och samma form. Om vi lägger ihop komponenterna R, M, I och P i diagram 1 till ett enda block, U (som t.ex. kan stå för "utrustning") får vi ett diagram av följande utseende:

Diagram 3



Gör vi samma sak med diagram 2 och "blockar ihop" M och P får vi också diagram 3 till resultat (de båda pilarna 1 och 4 som utgår från O i diagram 2 kommer att sammanfalla).

Diagram 3 är det grundläggande principdiagrammet för beskrivningen av "arbetssystemet". (Det är i själva verket så generellt att det kan tillämpas på de flesta mänskliga aktiviteter). Vad det framför allt visar är att utflödet från systemet, y, är ett resultat av *hela* samspelet mellan systemkomponenterna. Operatörens inflöde och utflöde är inte samma sak som in- och utflöde för hela systemet.

De här ovan diskuterade diagrammen kan användas för att illustrera innebörden av olika sätt att studera och beskriva arbete. Låt oss som ett exempel anta att diagram 3 ovan handlar om svarvning. O är svarvaren, U svarven. För olika ändamål och

The first of these figures are completely described in the text, while the other two are modifications of the first one. It could be difficult to follow the text without at least some comments on these two last figures. The whole section does, however, seem to be unnecessarily laborious at the first glance. The rationale for bringing in this kind of description of the work becomes apparent when it turns out that the section following these three figures deals with principal ways of describing work. The three figures are used to illustrate the logic of different ways of studying and describing work.

The two figures which are left out by the talking book editor without being described in the text are not crucial for understanding the passage where they appear, but the reader is referred back to them in the following section. It will probably be very problematic to acquire the contents of this section without the figures. Verbal descriptions of them would, however, miss the point. The figures have to be available simultaneously with the reading of the following section.

The rest of the symbolic figures in this book are box models too. They are all left out, without any apparent consequences for the talking book reader. Either they appear superfluous to the reader, or are they described in the text.

A few figures from a book on criminology will provide the last examples of left-out symbolic and analogue figures[6]:

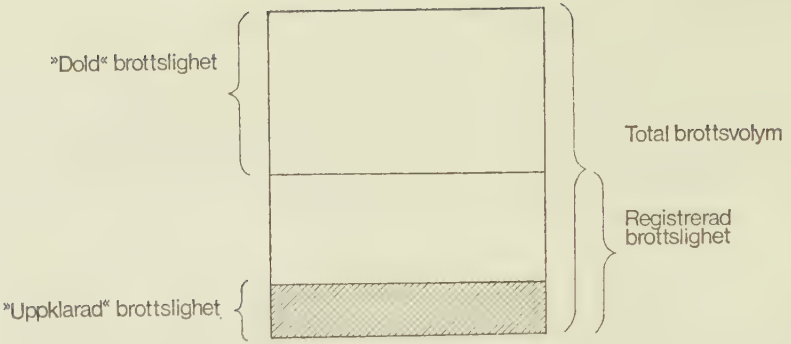
Volym och selektion

Begreppen "volym" och "selektion" är två empiriska termer som i dag används rätt ofta i deskriptiva kriminologiska undersökningar.

Med brottslighetens "volym" åsyftas antalet brottsliga handlingar under en viss tidsperiod, i allmänhet ett år. Volymen kan emellertid referera till olika *delar* av brottsligheten. Man kan antingen åsyfta den *totala* volymen, dvs det verkliga antalet faktiskt förövade brott, eller *den registrerade* volymen, dvs det till polisens kännedom komna och registrerade antalet brott. Förhållandet illustreras av följande figur.

Med "dold" brottslighet åsyftas den brottslighet som inte registrerats därför att den antingen inte upptäckts eller upptäcks men inte registrerats av andra skäl, och med "uppklarad" brottslighet den brottslighet

[6] The text tells why "registered number of offences" is not a good index of cirminality. The figure is a graphical illustration of the same thing. From: *Samhällsförändringar och brottslighet.* p 24–25 (Red.) Daun, Å., Börjesson, B. & Åhs, S. Tidens Förlag 1974.



som (enligt givna definitioner) "klarats upp" av polisen — i allmänhet genom att någon person övertygas om brottet.

Proportionerna mellan de olika delarna i figuren varierar mellan olika brottstyper. Vid brottet mord torde den registrerade brottsligheten praktiskt taget sammanfalla med den totala brottsligheten och den uppklarade likaså, medan vid skattebrott och vissa trafikbrott den registrerade och uppklarade brottsvolymen torde sammanfalla med grundstrecket, endast någon liten promille av alla sådana brott blir registrerade.

The figure summarises the information already given in the text. No information is thus lost for the talking book reader.

The next example is a figure which specifies the development of different types of offences from 1950[7]:

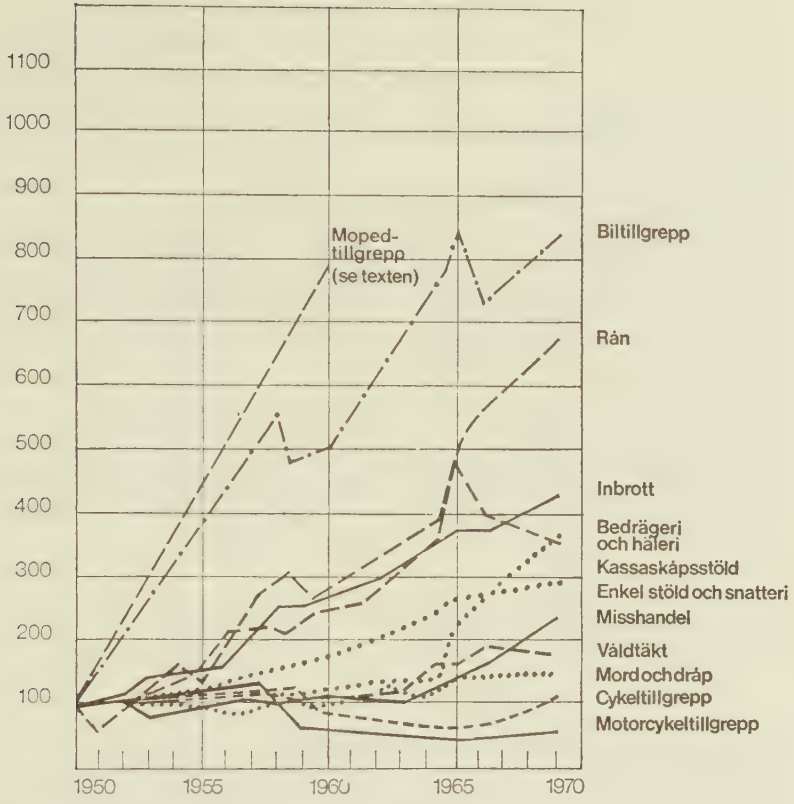
Beträffande *brottsförändringarna* visar det sig att de olika brottstyperna har haft delvis olika utveckling. Om man — för jämförelsens skull — mäter de procentuella förändringarna av vissa olika brottstyper med utgångspunkt i året 1950, framkommer de kurvor som återges i figur 3.

Av denna framgår, att *motorfordonstillgrepp* visat den kraftigaste ökningen. Mopedtillgreppen, som inte går att räkna in i en grafisk framställning av denna typ emedan det inte fanns några mopeder alls år 1950 (och följaktligen inga att stjäla) ligger i dag på ca 15 000 anmälningar. Biltillgreppen har 8-dubblats och torde nu överstiga 30 000 anmälningar.

En oroande utveckling visar *rånen,* som numera anmäls i ett antal av 1 500 per år. Ser man närmare på figuren kan man emellertid konstatera en extrem ökning just omkring 1965, vilket gör det sannolikt att åtminstone någon del av ökningen kan tillskrivas en annan och bättre redovisning. **(För den kvantitativt underordnade gruppen post- och bankrån är emellertid ökningen helt klar: Dessa brottstyper var helt okända för 10—15 år sedan.)**

***Inbrott* av olika slag tillhör de "stora" brottstyperna i och med att det anmälda antalet i dag uppgår till 140 000. Förändringarna för dessa brott**

[7] "Figure 3" in the text shows the trend for a number of different types of offences since 1950. The text gives short comments on each of the different types. (Ibid., p 33—34).



Figur 3. Brottsförändringar 1950—69 för vissa brottsbalksbrott.

har haft ett mera jämnt förlopp sedan 1950 och ökningen är påtaglig, nämligen mer än en 4-dubbling. Analyserar man här detaljerna i den preliminära statistik som presenterats för åren 1968—1971, visar det sig att det bl a är inbrott i lägenheter, villor samt källare och vindar som har den största ökningen. Detta kan knappast ha med statistikomläggningen att göra, men tyder på en reell ökning. Försäkringsbolagens statistik visar här samma trend.

Kassaskåpsstölderna — en liten, men exklusiv brottsgrupp — visar en uppåtgående tendens till 1965, men har därefter påtagligt sjunkit.

Bedrägerikurvan ökade från 1965, huvudsakligen p g a checklönesystemet, fram till 1970—71, varefter det har blivit en viss stabilitet i hela brottsgruppen med en kraftig nedgång i checkbrotten. Orsaken är givetvis slopandet av den s k bankgarantin 1 juli 1971.

Den största av alla brottsgrupper, *enkel stöld och snatteri*, har tredubblats sedan 1950 enligt statistiken. Antalet registrerade brott uppgår i dag till ca 160 000. Under åren efter 1968 tycks den största ökningen ha varit i gruppen tillgrepp av motorfordon som har ökat från 45 000 till 70 000. Däremot har antalet anmälningar från varuhus och butiker stabiliserat sig på ca 20 000.

Av övriga tillgreppsbrott är av intresse att märka *motorcykel- och cykeltillgreppens* förändringar. De förstnämnda har sedan 1950 visat en kraftig nedgång och någon påtaglig ökning kan ej spåras. Annorlunda är det med cykeltillgreppen, som först kraftigt gick ned fram till 1967, men därefter har ökat mycket kraftigt. I dag (1973) anmäls inte mindre än 80 000 cykeltillgrepp.

Slutligen återstår att säga några ord om *våldsbrottsligheten*. Totalt sett utgör våldsbrotten den brottsgrupp som har ökat minst sedan 1950. Antalet mord och dråp (inkl försök) har varit tämligen konstant, vilket för övrigt även kan avläsas i en helt annan statistik, nämligen dödsorsaksstatistiken. Antalet personer som har avlidit genom mord och dråp har sedan början av seklet legat på mellan 50 och 70 personer per år. Någon ökning under de senare åren kan inte spåras.

The figure is described in the text. It adds some details which are not contained in the text, but these details are not needed in order to comprehend the discourse. This is valid also for a couple of other analogue figures in the book.

10.3 Implications of the follow up study for the theoretical perspective on the role of graphical information in text books

It seems from the examples given above that most of the figures which were excluded were described in the text. Some of them gave additional information on topics treated in the text, but in none of the cases did the exclusion of them cause any break in the discourse. This conflicts, to a certain extent, with an assumption underlying both the first and the second conception of the problem with figure descriptions in talking books:

> "The function of graphics in text can be reinstated by verbal descriptions (or tactile representations of the figures). Verbal and graphical components in a text convey separate components of a message. Which component is to be represented in which form is, to a certain extent, the author's choice."

Much of the information conveyed by graphics does, however, exist in verbal form in the discourse as well. Why are the graphics there then? They do not add any information that is not already present in the text. The remaining possibility is that the graphical information is intended only to support the readability of the text. Graphics are, in that case, merely aids in the reader's processing of the verbal information. They are there to relieve the reader from some of the mental effort it would otherwise take to assimilate the logical content of the text. If this is the case, the implications for talking book editing are changed somewhat. Graphical information is not substitutable for verbal information in a text. A translation of a diagram, organisation chart or a symbolic model of something into connected discourse totally misses the point. The function of graphic information has to be

restored by other means. Conception I and II were both based on the premise that verbal representation *could* replace graphic. The advice to narrators and editors concerning representation of figures in talking books rely on this premise. Graphically represented information and verbally represented information are both components in the total text structure to be acquired. If graphic information is rather an aid for making the verbal text more easily accessible and more flexible to process, nothing is gained from verbal representation of it. Rather, the inherent drawback of the medium (the tape and the tape recorder) is more pronounced than if the figures were left out. Alternative means to graphical information have to be found, which make the spoken text equally well-structured and accessible as the printed text in the inkprint book.

Before suitable means can be found, the actual influence of graphical information on the reading process has to be determined. How does graphical information affect the reading process? A theoretical model of the reading process, incorporating effects of design elements in the text, has to be found. Such a model could give guidelines to the editors concerning effects of different editing operations.

11. Does design make a difference?

11.1 Motives for the use of text book illustrations

The empirical investigations of graphics in text books produced as talking books have revealed some interesting facts. The use of graphical material has increased considerably during the time production of talking books has been going on. This increase is, however, limited to books for comprehensive school and upper secondary school. No corresponding increase can be noticed in books for the academic levels. Furthermore, the increase is, to a considerable extent, ain increase in the volume of graphics in the books; the instructional value of the graphics has not been increasing systematically.

It seems from these results that if there is a visualisation of text-books going on, it does not reveal itself in an increased importance of graphics as information conveyors in the books; the text is still by far the most important vehicle of knowledge. No trend away from this can be traced in the data. It seems evident from the results of the study of graphical material in talking books that the most information rich figures have not increased in frequency to any considerable extent during the period studied.

Against this background it is tempting to conclude that "visualisation of text books" is just a myth. If we for the moment reject such a conclusion, what other meanings could be ascribed to the concept "visualisation"? Why are figures used in texts in general? We shall review some of the arguments put forward by authors and publishers in favour of graphical material in texts below. We will also try to illuminate the effects of illustration of a text on the reading process. Some research which might throw light on the concept "visualisation" will be reviewed.

The reviews in Section 8.2 above showed that a regular use of illustrations began to appear in books during the middle of the 19th century. It is not quite clear what the motives for introducing illustrations in the textbooks really were. A review of consecutive editions of 19th century textbooks where illustrations were introduced showed that in no case was the introduction of illustrations explained by author or publisher. The public commission of 1887 responsible for examining text books had the following opinion on the topic:

> "As schools nowadays have access to wall charts, which in general contain what can be considered necessary to give the children a vivid picture of the essential parts in the stories it does not seem necessary to incorporate illustrations in the textbooks. The committee does not have any further proposals relevant to this question, since the use of good and carefully selected illustrations cannot be denied, while on the other hand it might prove difficult to include such without making the book considerably more expensive."
>
> (Author's transl.)

The school book commission of 1927 has but one comment on the use of illustrations in text books:

> "To use reproductions of masterpieces, where it is possible, is of course a good way to awaken interest and feeling for the creations at art and beauty."
>
> (Author's transl.)

The school book committee of 1945 sent out a questionnaire concerning teachers opinions on text books. The teachers in their replies stressed the role of text book illustrations for the advancement of interest and learning:

> "It is beyond discussion, it is pointed out, that for example a history book embellished with vivid pictures of the kind referred to here, could be enjoyable and imaginative, and to a great extent support a lasting memory."
>
> (Author's transl.)

The surveys made by the school book committee of 1945 revealed a lot of dissatisfaction with text book typography and illustration among teachers. Text books were compared with journals, newspapers etc, and jugded totally inferior to these from informative and motivational standpoints:

> "Illustrated journals and brochures of different kinds utilise the reader's inherent disposition to acquire knowledge with a minimum of effort. Text books have much to learn, and they are plainly forced to keep up with the material the children are confronted with at home in these respects. If this is not done, the young are not to blame if they do not pay any attention to the text books."
>
> (Author's transl.)

The next step is the development of the illustrated text book to a "lexicovisual" book (Lidman, 1969). The typographical lay out of the visualised book is rather different from a regular book. The connected discourse is broken up, and the text is centered around pictures, drawings and diagrams of different kinds.

The principles for lay-out and design of advertisments and newspaper pages also came to influence text book design (cf Pederby, 1969, p 15). The Swedish text book editor Sven Lidman (who introduced the term "lexicovisual design") has applied typographical principles from newspaper layout to text book editing. He uses the term "lexicovisual design" to stress the intimate interaction between text and illustration. The parallel with "audiovisual presentation" is apparent. In the same way as auditory and visual components of a presentation are dependent on each other, the pictorial and verbal components of lexicovisual design are intended to complement one another.

There are, however, rarely any references to research on reading in the arguments for visualised text book design. Lidman offers an exception[1]:

> "Torsten Husén has once with the pyramide as a graphical symbol—the tringle of methods—specified how much is retained in memory after three days:

[1] Lidman does not give the source of this quotation. The author's search through Husén's published work has been unsuccessful.

Text only—about 10 % of the material is retained.
Illustrations only—about 20 % of the material is retained.
Illustrations and text combined—about 65 % of the material is retained."

(Lidman 1966, page 24)

It does not seem, however, that these results apply to connected discourse. At least it is an undue simplification of matters when it comes to acquisition of *text*.

There is, on the other hand, research on reading which might provide rationales for using "visualised design" of text books. We will review some of the main studies below.

11.2 Effects of illustration of text on the reading process and on retention of information

Section 11.1 seems to demonstrate a consensus among authors, publishers and media specialists that graphic representation is valuable. The arguments, however, vary. Sometimes one almost gets the feeling that visual design is considered as some kind of universal remedy for educational problems. It is rather easy to find proponents for the use of illustrations in text materials. It is, however, not as easy to find arguments accompanied by research evidence for its value. Fleming (1967) writes:

> "It is almost indisputable that the lavish use of illustrations makes modern textbook more attractive, and some research with younger children supports this view. However, the case for older learners is much less well established, and one wonders what essential educational role is served by the illustrations in many of the current printed materials. Illustrations certainly add to the size and cost of books, but what evidence is there that they add proportionately to learning?"
>
> (Page 246)

Samuels (1970) made a review of research on the "effects of pictures on learning to read, comprehension and attitudes", which underlines Fleming's viewpoints:

> "1. The bulk of the research findings on the effect of pictures on acquisition of a sight-vocabulary was that pictures interfere with learning to read.
>
> 2. There was almost unanimous agreement that pictures, when used as adjuncts to the printed text, do not facilitate comprehension.
>
> 3. In the few studies done on attitudes, the consensus was that pictures can influence attitudes.
>
> Should pictures be used as adjuncts to printed text? The answer depends on the objectives. If the objective is to promote acquisition of a sight vocabulary, the answer would seem to be 'no'. If the objective is to facilitates comprehension, the answer is less definite. Although the research, in general, does not show that pictures aid comprehension, neither does it show that it hinders comprehension. Much research still needs to be done on the effect of pictures on attitudes."
>
> (p 405)

The lack of studies demonstrating the advantages of illustrations in textbooks indicate that the development in this respect has not been governed by educational

research. It is possible that lexicovisual design just reflects a more extensive use of illustrations in textbooks. Such a development would of course be more favourable to talking book producers and visually handicapped students than an increasingly efficient use of graphical material in text books.

The lack of scientific arguments in "editors' forewords" etc must not be interpreted as if there were no scientific support for the use of graphic information. There is a lot of educational and psychological research, mainly on reading and audiovisual media, which might support the extensive use of graphic information in text books. We will review these two research fields in the remainder of Chapter 11.

Comparisons of educational media have taken a good share of educational research since the Second World War. Several journals have this topic as their primary interest area. The "AV Communication Review", the "Audio Visual Instruction" and the "Audio-Visual Media" are among the most well-known. Much of the research done in this area has concerned the simultaneous presentation of pictorial and verbal material. Lidman's (1969) use of the term "lexicovisual design" also suggests that "AV-research" might provide the scientific foundations for an analysis of visual text book design.

One of the major concerns of AV research has been the study of simultaneous visual and auditory presentation. Effects of design features in visual presentation on retention and learning have also been studied. Some typical research questions are:

> "What is the value of pictorial embellishment in instructional programs?" "Is colour TV superior to black- and white TV with respect to learning and retention?" "To what extent do statements presented through different media preserve their equivalence?"

The normal text book has seldom been the object of audiovisual research. The focus of interest has been various technical presentation media. It seems, however, that the vast majority of studies have failed to reach any conclusive result. No theoretical guidelines for the design of educational materials have been offered. Lack of rigor in the theoretical and methodological framwork might explain this failure. Most audiovisual research is based on Stimulus-Response theory. It was connected to S-R theory via educational techology. Educational technology is atheoretical in the same sense as Skinnerian behaviorism is atheoretical. This means that the educational materials designer accomplishes a good final product by continous revision based on empirical tests of preliminary versions. The S-R-principle of reinforcement and knowledge of results which educational technology relies so heavily upon does not, however, give any guidance in the initial design of educational materials.

There are also other versions of educational media research than those based on the psychology of learning. AV Communication review devoted an issue (vol 10, nr 5) to the contributions of perception theory to audiovisual education. The articles appearing in this issue, however, all dealt with pictorial representation of

reality in education. The interplay between verbal and pictorial components of a text was not considered. Applications of perception theory in educational media design seem to concern the design of illustrations. In Olson's (1972) words, perception theory is occupied with the problem of "mapping sentences onto reality". The corresponding problem of "mapping sentences onto sentences" is not treated. This means that the principles offered by perception theory are valid only for iconic illustrations.

Regardless whether the AV research has been based on learning theory or perception theory; it has shown remarkably little interest in problems of definition. The methodological and theoretical shortcomings of audiovisual research can be illustrated by its confusing use of the concepts "Medium" and "Simultaneous presentation". "Medium" has been used for "sensory modality" (as in "audiovisual medium") as well as for representation forms (as in pictorial and verbal media). It has been used for the display and storage of information (as in the "textbook-medium") as well as for the distribution of information (as in mass-media).

The term "simultaneous" has been used in a equally confounding way. The problem with simultaneous presentation of information which has engaged educational media research so intensely has thus been formulated in several, sometimes conflicting conceptual forms:

1. The simultaneous presentation of auditory and visual representation of the same referent has been the basic paradigm (cf Ahlström, 1969).
2. The simultaneous presentation of different representations of aspects of the same referent, each to one sensory modality, is the paradigm describing educational film or reducational TV.
3. The simultaneous auditory presentation of two different referents (spoken discourse), one through each ear is an example of the paradigm Broadbent (1958) introduced. The conclusion of these studies is that man acts as a single channel. This means that there is a bottleneck (the single channel) somewere in the processing of sensory information that just lets one message through at a time.
4. The parallel presentation of different representations of the same referent (or different aspects of the same referent) to the same sensory modality is the paradigm of interest to the textbook author using illustrations in the text.

The results and conclusions of studies of simultaneous presentation of information have been rather confusing. Experiments made under one of these settings have been generalised to other settings. Results achieved under the conditions described under "2" above have been used to motivate design according to condition "4". The validity of this generalisation has been questioned with reference to the third condition.

Audiovisual research comparing different presentation modes does not seem to

contribute to a theoretical description of how verbal and pictoral components of a text interact.

There are, however, some studies of related problems which are relevant here. The Swedish Broadcasting Company has a research group which has studied the design of news programmes in television (Findahl & Höijer, 1976). The main findings of these studies are:

- Both different types of illustration and verbal repetitions can improve retention of what has been said in a short news item presented by a newscaster. Improvements in retention of up to several hundred percent can be obtained using this technique, compared to when only the newscaster is shown. On average, this technique improves retention by 50 %. A similar result is achieved if the causes and consequences of the reported event are repeated verbally.
- What the TV audience remembers of a news item is directly correlated to the illustrations accompanying it. This result is valid irrespective of the particular form of illustration chosen. Still photographs, overlaid texts and drawings all give the same effect.
- Maps, pictures of places or persons often give the result that these features are remembered. Pictures which can show the cause or consequence of an event do on the other hand transfer to all parts of the news item.

Pictures do apparently aid the retention of the illustrated aspects or phenomena. The study however also points out that this increase in retention can be achieved by means other than illustrations. Repetitions of the spoken message as doublecopying of some relevant facts on the TV-picture has the same effect.

If we try to translate these findings from design of TV-program to design of texts we may formulate the following hypothesis:

> (1) "A number of different editing operations, among which the use of graphics is one, give the same effective conditions for the reader to acquire and retain the text".

The finding that illustrations, repetitions etc are functionally equivalent in directing the TV-watchers attention to different parts of program is presumed to be valid also for normal reading situations. This would mean that substitutes for graphical material in talking books might be something other than some kind of representation of the graph or picture as it appear in the text. Copying of important parts of the text continously on a parallel track might for example fill the function of a figure that structures the content of a chapter in the beginning of it. Context-pictures setting the scene for a dialogue in a foreign language reader might be substituted by some kind of appropriate background sounds typical of the situation illustrated.

The aim of the editing operations must be to break up the sequential flow of information in the connected discourse so the reader of the talking book can get the same pattern of information presentation as the reader of the inkprint book gets.

The same facts or aspects of the text should be stressed in the talking book as in the inkprint book. The implications of the studies of television news programmes for talking book production are that printed and spoken text can give equally favourable reading conditions to the extent that a sound recording permits connected discourse to be structured through editing operations. The main obstacle for this kind of editing in the talking book is the sequential character of the medium presenting the text: the tape recorder and the magnetic tape. A common characteristic of the editing operations causing the effects in the TV-news studies was that they broke the sequence of information presented by the studio-reporter. The TV-screen permits such editing operations. If the presentation medium is a conventional tape recorder instead, this kind of editing becomes much more difficult.

It is not meaningful to test hypothesis (1) in the form it is stated. It must somehow be formulated to predict the appearance of an effect, not the absence of one. In its present form the hypothesis states that no difference in retention and ease of acquisition of a text will appear over a wide range of editing operations. The point in formulating the hypothesis in its "passive" form is just to stress that there are alternative design-elements to graphical information which will function in the same way as graphical information does. If this is so, verbal description might perhaps not be the most convenient substitute for graphical information. The verbal descriptions might perhaps even totally miss the function of their prototypes.

The formulation of an "active" hypothesis might start with the assumption that organisation of the text in a talking book is less convenient to the reader than the organisation of the text in an inkprint book. Exactly *how* reading is affected by the two text-organisations is not known. Over reading behavior, mental organisation of the text in a super structure during reading, short- and long term retention might be influenced. In what ways and to what extent is not possible to predict. Instead of formulating a more detailed, testable hypothesis, we formulate a general question which can perhaps be answered by existing research results:

> (2) "How is overt reading behavior, acquisition of a super structure for the text, and retention of the text, affected by the talking book format versus the inkprint format of a text?"

In line with the requirements put on the two precedent conceptualisations of the problem of graphical material in talking books, this one also has to have some practical implications for the actual production of talking books. Thus, inherent in the answer to the above stated question, the following question should also be answered:

> (3) "In what way could the functional characteristics of an inkprint text (from the readers point of view) be preserved when it is converted to talking book form?"

The mere formulation of these questions give some hints to where to look for an answer. Question (2) concerns the effects of text design on readability. A talking

book edition and an inkprint edition are just seen as design alternatives, affecting behaviour in different ways. Question (3) concerns the possibilities to rule out the differential effects of the two alternatives. These are the domains of reading research. Strangely enough, readability research has not paid any attention to problems of text design. It might be, however, that design problems have been dealt with under other headings within the total field of reading research. The JER review of reading research might elucidate this possibility.

The Journal of Educational Research has since 1933 summarised research on reading. The summaries are partitioned into "The sociology of reading", "The physiology of reading", "The psychology of reading" and "The teaching of reading". These summaries are reviewed in the JER 1974. Table 11:1, which is excerpted from this issue of the JER, shows the result of this review.

Table 11:1. Number of studies in 4 different areas of research on reading (excerpt fom the JER 1974, p 391).

Year	Sociology	Psychology	Physiology	Teaching	Total
1962	26 (17.6)[2]	51 (34.5)	6 (4.0)	65 (43.9)	148
1963	18 (11.2)	47 (42.0)	7 (6.3)	40 (35.7)	112
1964	40 (21.3)	47 (25.0)	11 (5.9)	90 (47.9)	188
1965	33 (23.7)	49 (35.3)	7 (5.0)	50 (36.0)	139
1966	12 (10.4)	48 (41.7)	9 (7.8)	46 (40.0)	115
1967	17 (11.9)	53 (37.1)	5 (3.5)	68 (47.6)	143
1968	17 (10.3)	68 (41.2)	9 (5.5)	71 (43.0)	165
1969	10 (6.5)	61 (39.9)	5 (3.3)	77 (50.3)	153
1970	8 (6.6)	62 (50.8)	11 (9.0)	41 (33.6)	122
1971	24 (13.4)	99 (55.3)	6 (3.4)	50 (27.9)	179
1972	22 (9.9)	125 (56.1)	22 (9.9)	54 (24.2)	223
1973	48 (14.8)	109 (33.6)	54 (16.7)	113 (34.9)	324
Total	275 (13.7)	819 (40.7)	152 (7.6)	765 (38.0)	2011

The psychology of reading and the teaching of reading are the dominating sections in the summaries. Several studies with different approaches to the problem of reading comprehension are included in the section on psychology of reading. A factor analytic approach is exemplified by the following study:

> "Davis [. . .], in a study similar to his earlier one, identified six separate skills. This later study is probably the most significant factor analysis of comprehension to date. He indicates that 32 percent of the variance was accounted for by a factor called memory for word meaning, and drawing inference from content accounted for twenty percent of the variance. Most of the remaining variance was accounted for by three factors: following the structure of the passage; recognizing the writer's purpose, attitude, tone, and mood; and finding answers to questions based on explicit or paraphrased information."
>
> (page 405)

[2] Percent of year's studies in the area.

The determinants of comprehension according to this study thus are "reader variables". Text variables do not, however, seem to be accounted for. The three factors "following text structure", "recognising authors intent" and "finding answers to questions based on explicit information" rely heavily on the kind of test material used. It would be very interesting to make a corresponding analysis of how the author's (editor's) way of structuring the text, his way of announcing his intent (with the help of advanced organisers for example), his way of making important parts of the text easy to find, would affect comprehension.

The review continues:

> "Perhaps the area receiving most attention was that of sentence structure and syntax as it is related to comprehension. Studies by Zeman [. . .], Darnell [. . .], and O'Donnell [. . .] all reported significant relationships between various types of comprehension and sentence structure. Gough [. . .] in two studies found that active sentences are verified faster than passive, and affirmative faster than negative; and, more specifically, the relation of verification time to sentence structure was not found to be an artifact of sentence length."

These are the variables discussed in Conception I which were considered too atomistic.

A single study of the interaction between "reader variables" and "text variables" is reviewed:

> "Oaken and Wiener [. . .] investigated the comprehension of good and poor readers as it relates to mode of presentation (visual or auditory) and found that good readers demonstrated their highest level of comprehension under the condition of good visual input, while the poor readers did best with auditory input."
>
> (Page 405)

None of the studies reviewed above has any *direct* implications for text design. They can provide a conceptual frame to describe reading but hardly any way to improve the readability of text. This is however not possible even with the indices designed especially for the assessment of readability.

Most of the studies on readability in addition lack the theoretical rigour needed to give specific recommendations as to how text should be designed.

There is some research on reading with a different perspective on the question of text design. Ausubel (1963) and Rothkopf (1970) have both engaged in research on effects of different techniques to improve retention of texts. Ausubel was among the first educational researchers after the S-R era who used texts in his experiments instead of "meaningless" trigrams etc. Much of his research has been concentrated on "advance organisers" and their effect on the acquisition process. The aim of advance organisers is to provide the reader with general introductory information, relating the contents of the text which follows to the reader's previous knowledge. Research on the empirical effects of advance organisers has however not led to any conclusive result. Barnes & Clawson (1975) summarise their review of research on advance organisers by stating:

> "The efficacy of advance organisers has not been established. Of the 32 studies reviewed, 12 reported that advance organisers faciltate learning, and 20 reported that they did not. When the variables—length of study, ability level of subjects, type of organiser, and cognitive level of the learning task—were analysed separately, no clear patterns emerged regarding the facilitative effects of advance organisers."
> (page 651)

Another approach to a theory of meaningful verbal learning is represented by Rothkopf (1970). Rothkopf has coined the expression "mathemagenic activities" to account for reader activities giving rise to learning. Most research on mathemagenic activities has dealt with "attention-directing" questions which are inserted into a text. Such questions have been shown to have a facilitating effect on learning (Faw & Waller, 1976). It has however also been suggested that the effects are due mainly to an increase in total study time brought about by the questions.

Research on text design and readability has utilised many approaches, and incorporated many variables.

Platzack (1973) has made an attempt to systematise the results and variables of readability research. He has identified six factors governing the readability of a text: "syntax", "typography", "content", "the reader's skills", "the reader's aims" and "the reader's mental efforts".

Platzack argues that it is possible to formulate a theory of reading which incorporates all these factors. Furthermore he has not found any evidence in his studies of readability which indicates that factors as for example social class and the abovementioned factors interact. The influence the factors exert on the reader is in the same direction for all readers.

Instead of using a correlational method, as most of the psychological readability studies have done, Platzack takes a psycholinguistic approach. The central features in Platzacks description of reading and text is the analysis-by-synthesis model of reading (cf Stevens & Halle, 1965), coding theory and generative-transformational grammar. This type of combination of pscyhological theory and linguistic theory could form a fruitful perspective on the relation between text design and text comprehension. Content, design and reading effort could serve as the cornerstones in a model of the role of text design on readability. The establishment of such a model is the aim of Chapter 12.

12. A tentative model of the role of text design in readability

The studies reviewed in Chapter 11 above can cast some light on the finding that graphical information seldom is needed for the *logical* coherence of the discourse. Graphical information often duplicates the text, or gives further details on a matter which is treated in the text. There seems to be both empirical and theoretical support for the hypothesis that graphical information is an aid to the reading process rather than a logically necessary step in the discourse. The studies by Findahl & Höijer (1976) showed that pictures act in the same way as repetitions of verbal constituents in a discourse. The analysis-by-synthesis model of reading could easily incorporate pictures as cues to the decoding of the text.

A model of the role of graphical information in texts should thus focus on its value as an aid to the reading *process*. To specify this role of graphical information, the model must be able to:

A. distinguish the *logical content* which the text should convey to the reader from the *psychologically motivated design features* of the text, which aims at facilitating the acquisition process. This means that the model must describe the contents of a discourse without reference to the actual form of representation used. It should not be possible to tell from the description of the content whether the author has used connected discourse or lexicovisual presentation.

B. describe the mental transformation of text to knowledge which goes on during reading.

C. describe different design features in the text in psychological terms. This is necessary if the model should be able to specify the role of design information in the mental transformation from text to knowledge.

The theoretical possibilities to fulfill these three requirements, thus opening up a possibility to establish a model of the role of text design in reading, will be examined below.

12.1 The model's description of text structure

Requirement "A" above might seem easy to fulfil. The intuitive approach is that "content" equals connected discourse, and "design" equals graphical information, chapter headings, use of italics or other typographic feature to stress certain parts of the text.

Such an approach does however immediately run into difficulties. Do "advance organisers", summaries and inserted questions belong to the "content" category or to the "design" category? In which category do repetitions or reformulations of a certain statement in the text belong? What about two different authors' versions of the same theme? Should cross references in the text be considered as "design" or "content" information?

Traditional ways of describing verbal matter provide no answer to these questions. Phrase grammars, for example, can just take account of intrasentence structure in texts. The main concern here is *inter*sentence structure. Psycholinguistic research has during the latest years become increasingly aware of the importance of intersentence structure for the comprehension of verbal matter. The research on text grammars (cf Petöfi, 1973) has provided a framework for the formulation of hypotheses concerning the effects on intersentence structure on text comprehension. An overview of this field of research has been given by Kintsch (1974).

The problem of finding a description of the knowledge conveyed by a verbal or graphical representation in a text book has appeared in several forms both in Conception I and Conception II above.

The application of Ackoff's classification of scientific models was such an attempt to describe characteristics of representations of knowledge. As Ackoff's main interest was to assess the descriptive capacity of the model, it is not possible to extend it to discriminate between verbal discourses. Verbal discourse represents the same level (viz "symbolic") in Ackoff's classification regardless of what information is conveyed by the text. It would be possible to use an analogue model as a substitute for a symbolic one with the content and meaning of the discourse quite unchanged. What is sought for is rather a conceptual system to describe the knowledge *contained in* the text.

The study of mental complexity of information is another aspect of the problem of mental transformation of text during reading. The experiments reviewed in Conception I (Ladefoged, 1959, Savin & Perchonock, 1965, Miller, 1956, Miller & McKean, 1964) all tried to define the relation between knowledge and its written representation. The vast majority of the studies in this tradition study the relation between syntax and psychological processes however. The relation between *inter* sentence structure and knowledge is not studied.

A system proposed by Kintsch (1974) provides a possibility of studying the psychological relevance of variables relating to inter sentence structure as well as to intra sentence structure. The basic entities which Kintsch uses to describe a text are *propositions*. A proposition is composed of one *predicator* and (at least) one *argument*. The predicator and the argument(s) can be single words[1]. They can, however, also be phrases, or even paragraphs. The basic constituent of the text description is thus not identified with a certain syntactic unit. Kintsch gives some examples of this:

[1] At the propositional level of representation words are replaced by "word concepts" (Ibid., p 12).

"Sentence (6)[2] also shows that propositions may be embedded within other propositions as their arguments. If such embeddings occur, there is an alternative notation that will be used frequently. There are three different propositions involved in (6), and it is sometimes preferable to separate these propositions notationally. This can be done by giving arbitrary names to the embedded propostions (we shall use Greek letters for this purpose). Thus, an alternative way of writing (6) is

(IF,α,β)&((TRUST,MARY,JOHN)=α)&(FOOL,MARY)=β). (6′)

Many sentences are based upon more than one proposition, like (6). The following sentences provide further examples of compounds:

The old man smiled and left the room. (7)
(OLD,MAN)&(SMILE,MAN)&(LEAVE,MAN,ROOM)

Mary claimed that the old man smiled and left the room. (8)
(CLAIM,MARY,α)&((OLD,MAN)&(SMILE,MAN)&
(LEAVE,MAN,ROOM)=α)

The snow melts slowly. (MELT,SNOW)&(SLOW,MELT) (9)"

(Ibid, page 13)

Propositions can together form a *text base*, which is a formal description of the structure of a text. Kintsch gives an example of a text and the corresponding text base. The text is a report of a psychological experiment:

"Reading Time

Introduction

This study concerns the psychological reality of propositions.

Method

Subjects. The subjects were 20 female students. All subjects were volunteers.

Design. Two independent variables were investigated in this experiment. The two variables were combined factorially. Forty sentences were used, some of which were 8 words long and some were 16 words long. Half of the sentences of each length were based upon three propositions and the other half was based upon six proposition.

Procedure. Subjects read each sentence separately and recalled it immediately in writing. They were instructed that recall need not be verbatim.

Results

The time which subjects took to read the 8- and 16-word sentences which were based upon six propositions was 5 sec longer than the time for the 8- and 16-word sentences based upon three propositions.

Discussion

The dependence of reading times upon the number of propositons upon which a sentence was based demonstrates the psychological reality of propositions. It may be concluded that subjects process propositions when reading."

(Ibid, page 19)

The corresponding text base is shown in table 12:1.

As the reader can see for himself, the description of the text is hardly more comprehensive than the text itself. This makes it difficult to use the system as it stands for descriptions of whole text books, or even parts of text books.

[2] "Sentence (6)" reads "If Mary trusts John she is a fool".

Table 12:1. A text base description of a text reporting a psychological experiment. (Source: Kintsch 1974. The corresponding text is quoted on page 112).

1	Reading Time(2&6&39&54)
2	Introduction(THIS,STUDY)
3	(CONCERN,STUDY,4)
4	(REAL,PROPOSITION)
5	(PSYCHOLOGICAL,REAL)
6	Method(7&11&29)
7	Subjects(STUDENT,SUBJECT)
8	(FEMALE,STUDENT)
9	(VOLUNTEER,STUDENT)
10	(NUMBER,SUBJECT,TWENTY)
11	Design(INVESTIGATE,EXPERIMENTER,VARIABLE)
12	(INDEPENDENT,VARIABLE)
13	(NUMBER,VARIABLE,TWO)
14	(COMBINE,EXPERIMENTER,VARIABLE)
15	(FACTORIAL,COMBINE)
16	(USE,EXPERIMENTER,SENTENCE)
17	(NUMBER,SENTENCE,FORTY)
18	(SOME,SENTENCE)
19	(LENGTH,SENTENCE,20)
20	(NUMBER,WORD,EIGHT)
21	(LENGTH,SENTENCE,22)
22	(NUMBER WORD,SIXTEEN)
23	(HALF OF,SENTENCES)
24	(BASE UPON,23,25)
25	(NUMBER,PROPOSITION,THREE)
26	(OTHER,23)
27	(BASE UPON,26,28)
28	(NUMBER,PROPOSITION,SIX)
29	Proceudre (READ,SUBJECT,SENTENCE)
30	(EACH,SENTENCE)
31	(SEPARATE,29)
32	(RECALL,SUBJECT,SENTENCE)
33	(IMMEDIATE,32)
34	(MANNER:IN,32,WRITE)
35	(INSTRUCT,EXPERIMENTER,SUBJECT,36)
36	(NOT,37)
37	(NECESSARY,38)
38	(VERBATIM,RECALL)
39	Results(REQUIRE,SUBJECT,TIME1)
40	(READ,SUBJECT,SENTENCE1)
41	(IN ORDER TO,40,39)
42	(LENGTH,SENTENCE1,43)
43	(OR,20,22)
44	(BASE UPON,SENTENCE1,25)
45	(REQUIRE,SUBJECT,TIME2)
46	(READ,SUBJECT,SENTENCE2)
47	(IN ORDER TO,46,45)
48	(LENGTH,SENTENCE2,43)
49	(BASE UPON,SENTENCE2, 28)

(Table 12:1 continued)

50 (LONGER,TIME2, TIME1)
51 (EQUAL,TIME2,52)
52 (PLUS,TIME1,SECOND)
53 (NUMBER,SECOND,FIVE)
54 Discussion(DEMONSTRATE,55,4)
55 (DEPEND,TIME,NUMBER)
56 (READ,TIME)
57 (HAVE,PROPOSITION,NUMBER)
58 (BASE UPON,PROPOSITION,SENTENCE)
59 (CONCLUDE,EXPERIMENTER,60)
60 (PROCESS,SUBJECT,PROPOSITION)
61 (READ SUBJECT)
62 (WHEN,60,61)

Furthermore, the regeneration of syntactically correct text from the text base requires that "cases" (cf Fillmore 1968) are denoted for some propositions. This complicates the notation still more.

There are other systems aiming at a description of the structure of texts which have been developed for experimental purposes. The "Circle Island" text which has often been used in experiments on discourse acquisition (see Fredriksen, 1975a), is described in terms of set relations. Figure 12:1 shows a graphical description of the set relations. The text has the following wording:

> "Circle Island is located in the middle of the Atlantic Ocean north of Ronald Island. It is a flat island with large grass meadows called *pampas*. It has good soil but few rivers and hence a shortage of water.
>
> The main occupations on the island are farming and cattle ranching. In general, the farms of the island are small, designed mainly to feed the farmer and his family. The ranches, less affected by the lack of water, are large enough to permit the ranchers to export much of their beef which is a Black Angus variety. In fact, beef is the only export of the Island. Since the ranchers are much more prosperous than the farmers, no ranchers are farmers.
>
> The island is run democratically. All issues are decided by a majority vote of the islanders. The actual governing body is a ten man senate called the Federal Assembly whose job is to carry out the will of the majority. Since the most desirable trait in a senator is administrative ability, the senate consists of the island's ten best proven administrators, the ten richest men. For years all senators have been ranchers.
>
> Recently an island scientist, Dr. Carl Oliver, discovered a cheap method of converting salt water into fresh water. He called this method saline recycling. As a result, some of the island farmers wanted to build a canal across the island's central region which is called the Queensland District. Some of the farmers formed a procanal association and even persuaded a few senators to join.
>
> The main opposition to the canal idea came from the ranchers who pointed out that if new farms deprived them of grazing land they would not be able to export sufficient quantities of beef to match the island's imports. Moreover, this deficit could not be made up by increased farming because farm produce is not in demand in New Hampton or in Beaton's Island which are the countries with which Circle Island can trade. They also pointed out that a large canal would upset the island's ecological balance because it would be a barrier to the several small species which migrate seasonally across the island through its central region.

The procanal association, calling themselves the Citizen's Development Association, brought the idea of constructing a canal to a vote. All the islanders voted. All the members of the procanal association and all the farmers voted for construction and everybody else voted against it. The majority voted in favor of construction.

The senate, however, decided that it would be too ecologically dangerous to have a canal that was more than two feet wide and one foot deep. After starting construction on such a canal, the island engineers found no water would flow into it and the project had to be abandoned. Many of the islanders were angry because of the failure of the canal project. It appeared extremely likely that there would be a civil war."

(Ibid, page 161)

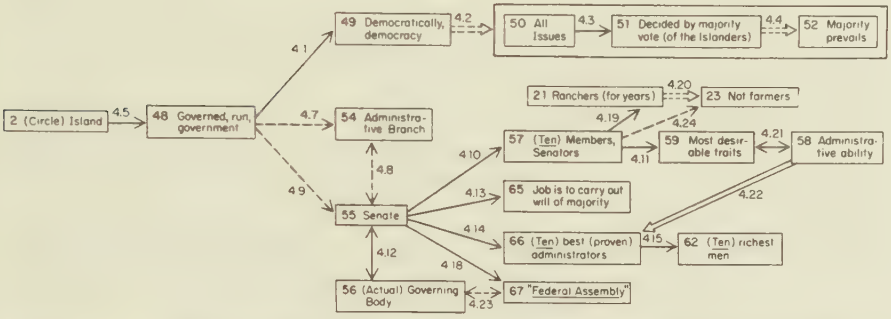


Figure 12:1. A graphical system used by Fredriksen (1975a) to describe set relations in a text (first paragraph of the Circle Island Essay).

Crothers (1972) used a method based on semantic analysis to describe the so called "Nebulae paragraph". Two alternative text versions of this paragraph are quoted below. Their common underlying structure is illustrated in Figure 12:2, which appears in Carrol & Freedle (1972, pages 252–253).

"*Nebulae – Version A.*

1. A nebula is any heavenly body which glows and has a relatively fixed location in space and looks fuzzy or nebulous. 2. There are two kinds of nebulae. 3. One kind is the nebulae outside our own galaxy. 4. The ones outside our galaxy are composed of stars. 5. Thus these nebulae are called galaxy nebulae. 6. Galaxy nebulae appear in clusters of from 2 to 30 galaxies. 7. The clusters of galaxy nebulae are spread rather evenly throughout the universe. 8. Galaxy nebulae look fuzzy because the overall nebula is seen, but the nebulae are so remote that their individual stars cannot be distinguished, even with the most powerful telescopes. 9. In fact, only three galaxy nebulae are close enough to be seen at all with the naked eye. 10. The other kind is the nebulae within our galaxy. 11. The ones within our galaxy are clouds of gas or dust. 12. Some of the gas nebulae are evolving to become stars, by expanding and contracting. 13. Gas nebulae glow because the gas itself is luminous, but dust nebulae seem to glow because they are illuminated by nearby stars.

Nebulae — Version B

1. A nebula is any heavenly body which glows and has a relatively fixed location in space and looks fuzzy or nebulous. 2. There are two kinds of nebulae. 3. The ones outside our galaxy and the ones within our galaxy. 4. The nebulae outside our galaxy are composed of stars. 5. Thus these nebulae are called galaxy nebulae. 6. The nebulae within our galaxy are clouds of gas or dust. 7. Galaxy nebulae appear in clusters of from 2 to 30 galaxies. 8. The clusters of galaxy nebulae are spread rather evently throughout the universe. 9. Some of the gas nebulae are evolving to become stars, by expanding and contracting. 10. Galaxy nebulae look fuzzy because the overall nebulae is seen, but the nebulae are so remote that their individual stars cannot be distinguished, even with the most powerful telescopes. 11. In fact, only three galaxy nebulae are close enough to be seen at all with the naked eye. 12. Gas nebulae glow because the gas itself is luminous, but dust nebulae seem to glow because they are illuminated by nearby stars."

(Ibid, pages 249–250)

All of these systems for description of the structure of texts require a detailed analysis of the text. It is thus very laborious to describe text passages longer than about one page with them.

The systems are, moreover, designed to produce and describe "artificial text". None of them have been used to abstract a text base from natural discourse. It is doubtful if it is possible to do this in a formal way at all (Petöfi, 1973). The tests which have been made with this ambition have been made with special text samples with special vocabularies. A system which can produce a text base from a text book by applying well defined grammatical rules does not exist. A lot of intuitive considerations are involved in all of the existing systems.

The description of a "natural" discourse obviously requires a much less labourious system than those reviewed above. The aim with the system should be that it can represent the text as the "ideal reader" represents it mentally after having read it. The notion of an "ideal reader" implies a reader without the limitations of a transient memory, failures in retrieval from long term memory, interference from irrelevant associations during reading etc. The "ideal reader" transforms the text to a unique final product regardless of the design of the text.

One basic assumption underlying most of the systems reviewed above ought to hold for the ideal reader; knowledge is preserved in some kind of semantic network. The nature and importance of the semantic rewrite rules between the nodes in this network differs in the systems described. The rewrite rules have to be very complex to form a text grammar which can manage any kind of text. This is the reason why most of the systems reviewed above only apply to experimental texts. Yet, every human reader must make inferences in the form of "semantic rewrite rules" to be able to transform the text to knowledge. Chafe (1972) has introduced "semantic constraints" as an alternative to rewrite rules to take care of this difficulty. Chafe assumes that a specific verbal statement is never specific enough to be encodable in isolation. All statements are interpreted against the background of what has been said previously and what is commonly known by the speaker/author and listener/reader. In a dialogue occurring in a text it is for

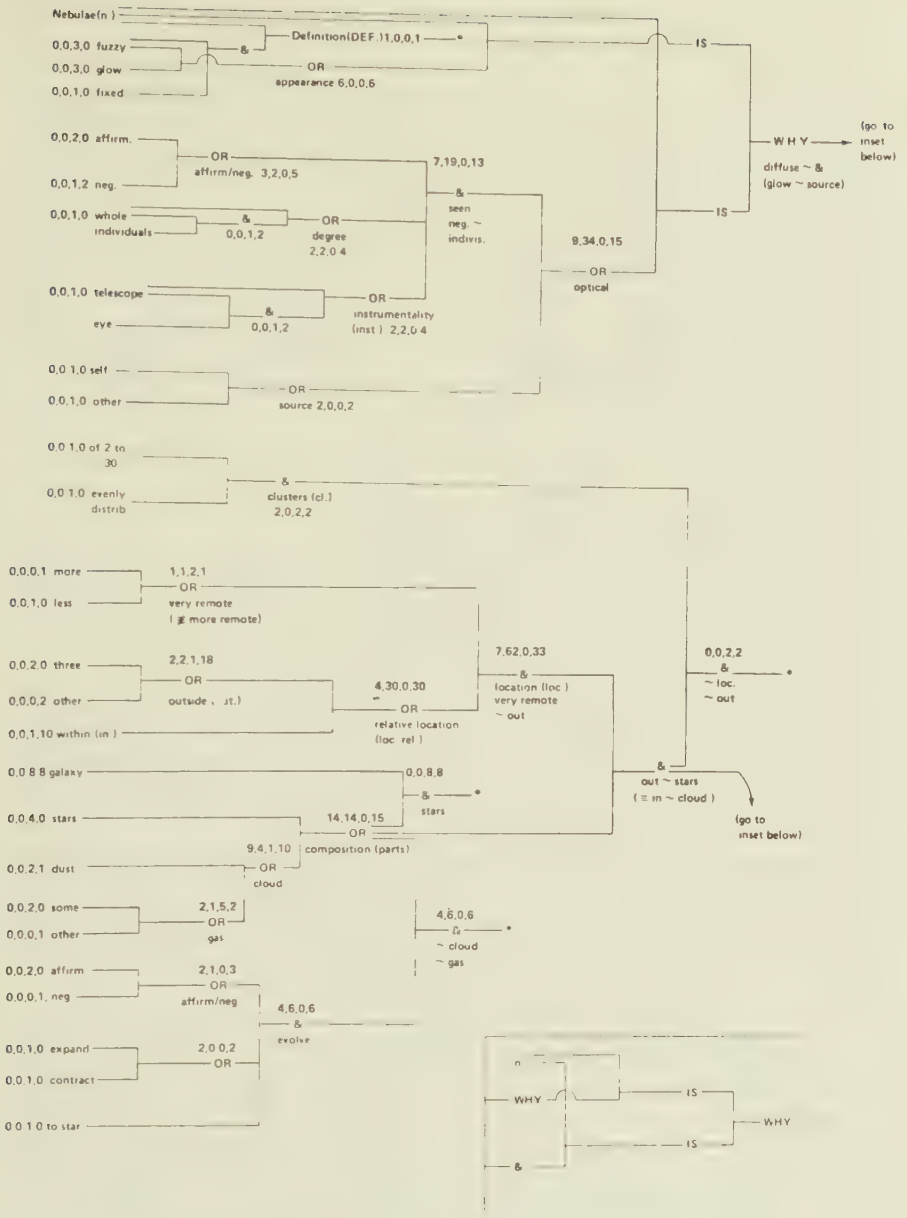


Figure 12:2. A graphical illustration of text structure (From Crothers, 1972, page 252–253).

example often assumed that the reader keep in memory who is speaking in his memory. The first two utterances in the dialogue are accompanied by a "tag" in the text which identifies the two speakers. The following two utterances, for example:

" '. . .', said Mary.
'. . .', replied Kate"

can be followed by several others without any identification tag. The reader still knows when Kate or Mary are talking. Some facts have to be kept in memory to constrain all the possible interpretations of a verbal statement to a few probable. Chafe labels this phenomenon "foregrounding".

So far, foregrounding seems only to be a valuable tool for describing the readers behavior and strategy during reading rather than the structure of the text. Chafe does not present any formal way of describing the structure of texts with his system either. Nevertheless, it is possible to build a kind of semantic network with the foregrounded elements in the text. The identification of the foregrounded elements in the consecutive sentences in the text offers some problems however, as there is no formal way to make this identification. The foregrounded elements have, therefore, to be identified "intuitively". This cannot be done uniquely, but the reliability in the identification ought to be sufficient to map the macrostructure of the text. This is after all what is expected from the ordinary reader.

The model of the role of text design in reading thus assumes that a text which is retained in memory can be described as a semantic network. One additional assumption has to be made in order to make it possible to use "foregrounds" as nodes in a semantic network:

> All statements in a text cannot be retained in memory. The reader uses certain basic statements or themes in the text to attach new statements to the semantic structure which is created during reading. These basic statements form the structure around which the text is built up. If they are lost from memory, the subsequent statements cannot be correctly interpreted and reliably retained in memory."

This assumption is necessary to make since Chafe himself does not identify foregrounded elements in every sentence. Rather, the elements he takes as instances of foregrounding are rather global: time, location, speaker (not very far from Fillmore's "cases" in fact). It is, however, not an unreasonable assumption. Fredriksen (1975a) says:

> "We begin with the notion that under normal conditions of exposure to discourse, our capacity to completely process and store all of the semantic information will be greatly exceeded. Consider the processing operations which are necessary to produce a complete semantic interpretation of a presented discourse. First, a semantic interpreter must generate from acoustic inputs a string of content words and syntactic markers for each sentence. Then it must identify the concept corresponding to each content word by retrieving the appropriate semantic information, and use this information together with the syntactic structure of the sentence to generate a relational structure linking these conceptual categories (cf. Fredriksen, 1972; 1973a, b; Bransford & Franks, 1971; Schank, 1972; Kintsch, 1972). Finally, it must store the resulting conceptual and relational structure. Since a certain amount of time would be required for each of these processing operations to be completed, it is reasonable to suppose that a period of time would be required after a sentence has been presented to complete the semantic interpretation of that sentence. In discourse, the rapid succession of sentences normally would be ex-

pected to prevent the semantic interpretation of each sentence from being completed. For example, Foss and Cairns (1970) have shown that interrupting sentence rehearsal will reduce recall.

Given that limitations on processing capacity exist, a discourse processing system would have to adjust to these limitations by selectively processing the input. The simplest possibility is that this selectivity is achieved in direct response to surface characteristics such as stress, intonation, and so on. Selectivity may also be achieved by reducing the presented semantic information through elimination of nonessential information (cf. overgeneralization, Dawes, 1966), and by using the context in which each new sentence occurs together with information selected from the current sentence and other previously acquired knowledge to infer conceptual and relational structure without completely analyzing each input sentence (cf. Schank, 1972). Both of these processes, overgeneralization and inference, ought to result in the subject's not acquiring a complete, literal semantic interpretation of a passage, but rather the gist of the passage."

(pages 158–159)

12.2 The reader's strategy in transforming text to knowledge

The problem of describing the knowledge structure of a text has been, if not solved, at least proved possible to overcome. The next step in the attempt to specify the role of text design in reading is a description of the *acquisition* of knowledge contained in the text; that is, a model of the reading process. To devise such a model is a still more formidable task than that of describing the text. It doesn't seem as if there is one single reading process suitable for a specific text. Different readers with a different previous knowledge of the topic treated in the text, and with different aims and ambitions for their reading, will proceed through the same text in different ways. The final *product* of reading might be the same for two readers with the same aim but different knowledge of the subject, for example, despite the fact that they have applied quite different strategies in their reading. Two readers with different aims may at the same time demonstrate the same overt pattern of reading, yet end up with totally different final "knowledge structures". A proofreader may, for example, proceed through a text in the same way as a child, just learning to read. The final product will, however, be very different.

It should be made clear immediately that we have to limit the scope of the current model of reading to the "ideal reader" (p. 116) in some respects to avoid difficulties: the reader will be assumed to have exactly that initial knowledge and reading aim which the author expected from the reader.

These assumptions can be justified to a certain extent since the area of application for the model is text book editing. Teachers and text book authors presumably aim at the same acquisition of knowledge for most of the pupils. The variation in prerequisites among the pupils is normally rather restricted (at least compared to the variations in a group of readers taken at random). The model of the acquisition process will thus start from the prerequisites possessed by the "normal" text book reader.

The reader is assumed to have resources for storage and processing of text. The

processing is assumed to take place in several consecutive steps, each one transforming the text to the next level. The input level can be graphemic, syntactic or semantic information (Craik & Lockhart 1972, Nilson, Marmolin, Smedshammar 1977).

At this stage the model runs into the same difficulties as the model of text structure (cf page 116). The transformation from graphemic to semantic information must be extremely laborious. A set of rewrite rules would be far too complex to manage during reading. The model of the reader's strategy overcomes these difficulties in the same way as the model of text structure did: "rewrite rules" are replaced by "semantic constraints". The reader approaches the reading task with certain expectations. A heading, or an introductory abstract constrains the expectations still more. Propositions are then interpreted in the constraining context.

Propositional information is stored and combined with the existing contexts into new foregrounds. When a foreground has served its purpose of attaching new propositions to the knowledge structure it is no longer actively preserved. Some of the propositions in the foreground will be assimilated into the final conception the reader gets of the text.

The common reader is not likely to achieve the final structure which the "ideal reader" is supposed to achieve. He has limitations in short term memory and text processing capacity which do not bother the "ideal reader". These restrictions are actually the motive for including the concept "strategy" in the title of this section. The reader has to adopt a strategy which economises his scarce resources for transient storage. During reading, he does not know for sure which of the elements in the sentence he is currently reading is going to be the foreground for elements in the next sentence. He may fail to "recirculate" some important foreground element, which results in a loss of all the information dependent on that element in the foreground hierarchy. The more hierarchically the structure of the text is built up, the worse the consequences of loosing such an element will be.

In the example in Figure 12:3, the nodes 2.1, 2.1.1, 2.1.2 etc will probably be lost if node 2 is lost.

If the foreground structure looks like the example in Figure 12:4, the consequences of loosing node 2, will be less severe.

As the reader cannot allocate sufficient resources to preserve every proposition in the text, he has to concentrate on those constituting foregrounds for further information.

The foreground structure of connected discourse often looks like a maze with "blind alleys" running out from most of the nodes. The blind alleys attach supplementary information to the main structure of the text. Thus, loss of such information is not detrimental to the coherence of the text. It is never foregrounded. The reader is, however, often able to fill in during the course of reading if the next node is part of the coherent discourse or if it is a "blind alley". If he foregrounds the wrong node in such a situation, the coherence of the text will probably be lost. The reader has to regress to the correct node and start reading the text from that point again.

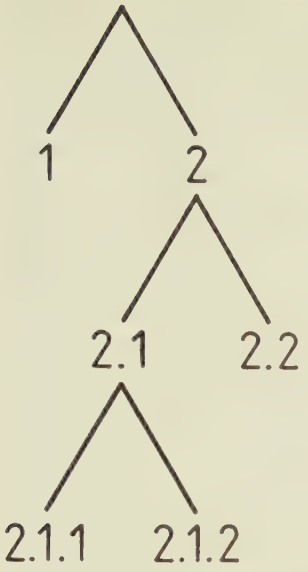


Figure 12:3. A hierarchic text structure. Loss of node "2" destroys the coherence.

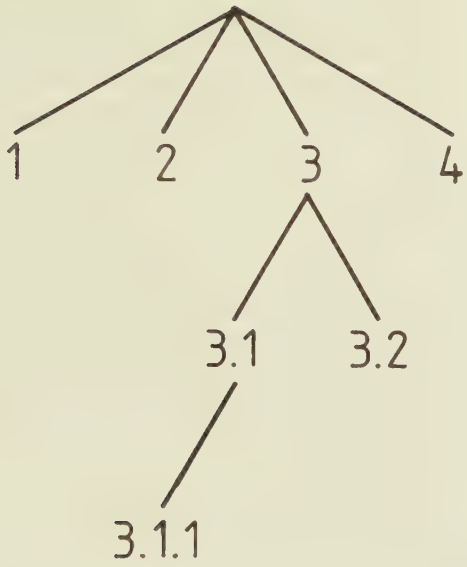


Figure 12:4. A mainly sequential text structure. Loss of a node does not necessarily mean that the coherence is destroyed.

Such regressions complete omissions in the foreground necessary to understand a certain statement in the text. Every statement in the text require some foreground in order to be understood. The amount of information required in the foreground can vary considerably. A set of complicated relations can constitute the foreground for one proposition, as in the example from the textbook in physics on page 124.

> "Every particle in the medium transmitting the sound is set in motion in a certain order and the particles can exist in different phases of the sound wave."

This sentence requires that the reader remembers what has been said about the concepts "sound transmitting medium" and "phases of the sound wave" in the previous passage.

The relations between amplitude, frequency etc has to be kept in the foreground to make the sentence in the example understandable. This places a heavy burden on the human storage capacity. In other cases, as, for example, an account of a series of events in a textbook in history, only the event taking place just prior to the one currently being read has to be kept in memory.

The reader thus has to organise the text to make it comprehensible. The sum of the single statements does not make up the whole of the text. Rather, they are meaningless to the reader until he can attach them to a organised structure inherent in the text. This organising of the text poses several problems for the reader.

He has, as input resources, a very limited capacity for both storing and processing graphemic and syntactic information. This information decays after a very short time interval or is replaced due to information overflow in STM. If it is not transformed to semantic information within the time limits set by STM, it is lost (cf page 119). This is what happens in experiments with embedded sentence structure (Coleman, 1962). STM is overloaded before it can transform the whole sentence to its semantic structure. The same thing can also happen at the semantic level. Propositions at a low level are replaced from STM before they have been integrated into a superordinate proposition. Decay of semantic information does not however proceed as fast as decay of graphemic and syntactic information. It is hardly correct to speak of decay at all in fact. Loss of semantic informaiton is due rather to distorsion or active exclusion from an established structure where a particular piece of semantic information does not fit. The consequences of "loss" of semantic information is often very severe if it is needed as foreground for other pieces of information. It is at the same time obvious that the end product of reading is not a direct image of the foreground structure of the text. Most of the semantic information seems to be deleted during or after reading. The remaining information is however not a random sample of statements from the text. It is an organised body of knowledge, mostly in accordance with the author's intentions. The reader thus has to assess some kind of priorities in the long term storage of information. This assessment is based mainly on the readers conception of the structure of the text. The readers initial concept of the text to be read is thus the first "semantic constraint" (in Chafes sense). A consequence of this point of view is of course that the learning of a text is only a modification of knowledge which the reader already has established. Gibson & Levin (1975, p 417) points out that writers ought to pay more attention to the preparatory context which can relate the texto to "older knowledge".

Walter Kintsch has in a paper presented at the SIPP conference on memory, in Uppsala 1977 (Kintsch, 1977), summarized the basic ideas underlying the view on reading put forward here. The number of propositions in a text, the number of arguments contained in the text, and the coherence of the text, are the main factors determining "readability" of a text. The effect of the first two of these factors has been described by Kintsch earlier (Kintsch et al. 1975).

The effect of the last factor "coherence" is described in the following manner:

All propositions which have an argument in common are connected to a network (see Figure 12:5). The reader constructs such a graph while he is reading. But, this construction process cannot be carried out in an unbroken sequence. The reader has to bring about a coherent text base to keep the constituents (propositions) in short term memobry until the structure of the text is revealed. If an argument contained in several propositions is lost from STM, the coherence is lost. This is the cause of several of the logical false conclusions appearing in Fredriksen's (1975a) experiment with the "Circle Islands" text.

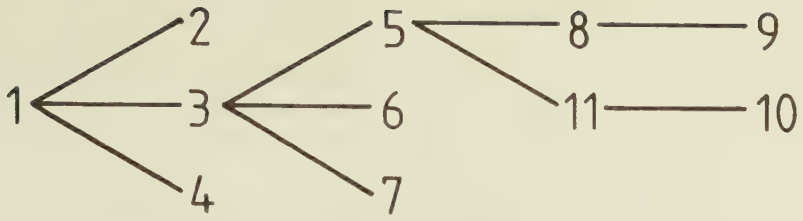


Figure 12:5. Relation between the propositions in a coherent text structure.

The context (e.g. the title) of a text tells the reader how to organise the text into superordinate and subordinate propositions. It has been demonstrated experimentally that a change of context for a text will influence the propositional structure of the readers text base (Fredriksen, 1975b).

The difficulties in acquiring a text can be plotted against STM capacity in the following way (Figure 12:6).

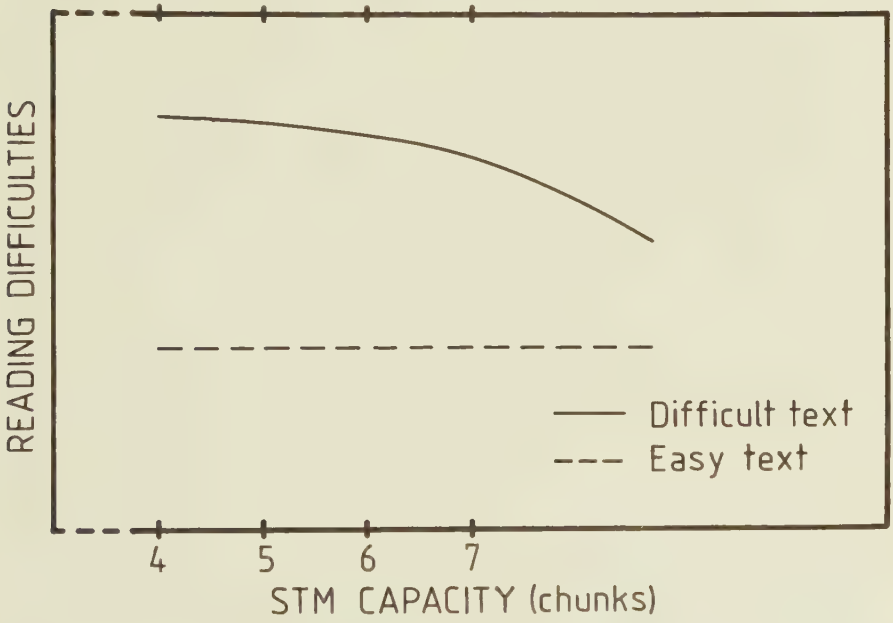


Figure 12:6. Relation between STM capacity and readability.

A consequence of this perspective on reading is that a general score of readability is impossible to assess. The readers STM capacity will always affect readability. The main factors determining readability are found *above* "sentence level". Reading research ought to concentrate on effects of the overall organisation of a text.

Foregrounding is the central concept in the model of the reader's strategy in transforming text to knowledge. It remains to be shown, however, how design elements in a text are utilised by the reader. This is the aim of Section 12.3 below.

12.3 A description of the psychological relevance of text design

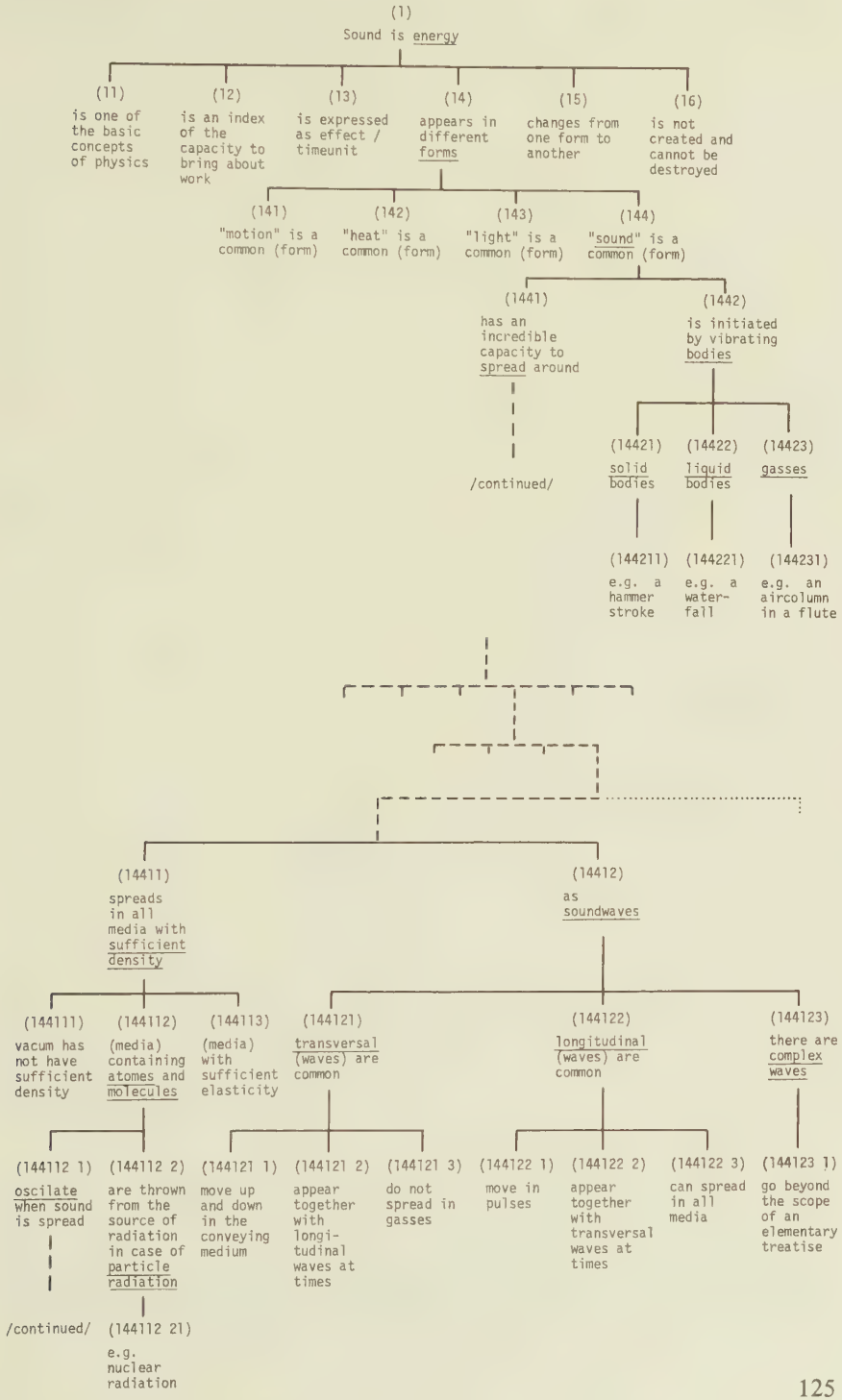
Sections 12.1 and 12.2 have provided descriptions of the relevant aspects of knowledge structure in text, and text processing capabilities of the reader. A description of effects of different design features can begin with a comparison between the knowledge structure and the surface-structure in a text. The example below is chosen from a text book in physics[3]. A linear version of the discourse, without any illustrations, headings, lines which are inset at the beginning of a new paragraph etc looks like this:

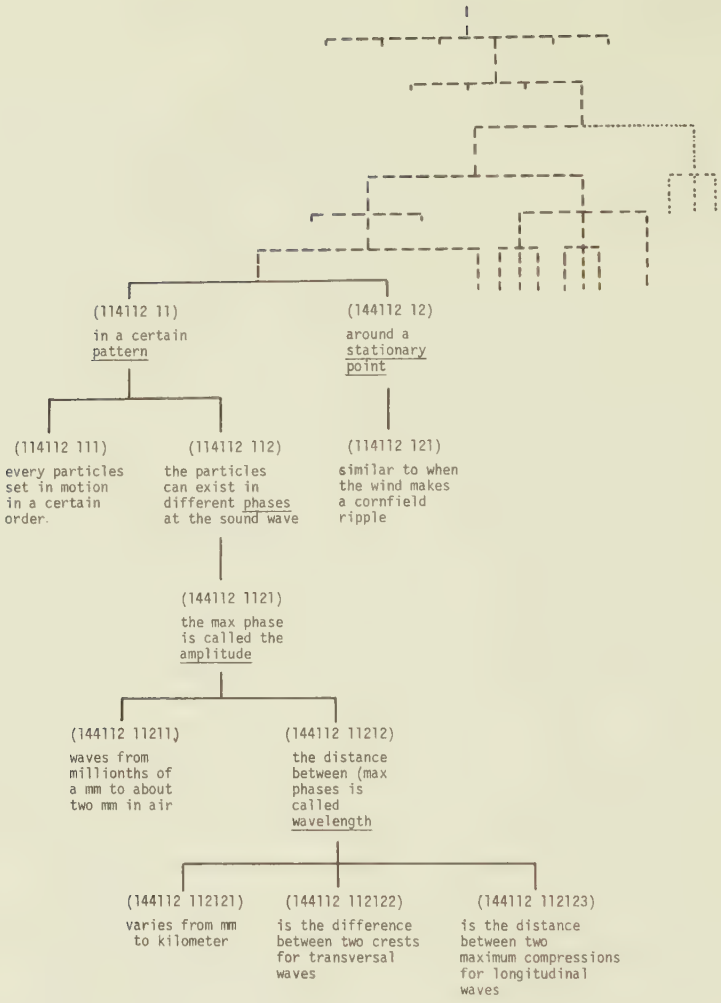
> "What we call sound is a form of energy. Energy is one of the basic concepts of physics. Energy is, simply speaking, an index of the capacity to bring about work. Energy can be expressed as effect per time unit, for example Kw/h. It is inherent in the concept energy that it changes from one form to another: it is thus not created, and cannot be destroyed. Some of the most common forms of energy is motion, heat, light and sound. Sound is a form of energy emitted by vibrating bodies. These bodies can be solids liquids or gasses. The sound from a hammer stroke is emitted by a solid vibrating body and the noise from a waterfall from a liquid. The tones of a flute emanate from a vibrating air column. The resulting sound has an incredible capacity to spread around. It can spread in all media having a certain density. In an absolute vacuum, however, sound can neither be emitted nor spread. The medium must contain atoms and molecules and have a certain elasticity to be able to transmit sound. Sound spreads in the form of sound waves. There are two main forms of sound waves: transversal and longitudinal. There are in certain cases more complex waveforms, but they go beyound the scope of this elementary treatise. Concerning transversal waves the particles are moving up and down in the medium conveying the sound, that is perpendicular to the direction the waves spread in. Concerning longitudinal waves the particles move in pulses in the same direction the waves radiate. Sound energy can spread in all media when it appears as longitudinal waves. Sound can spread in solid materials and in liquids both as longitudinal and transversal waves. The two wave forms appear together at times. When sound spreads in air, the molecules in the air oscillate in a certain pattern, but around a stationary point, similar to when the wind makes a cornfield ripple despite that the single cornstalks remain in their positions. Sound radiation differs from particle radiation in this respect; nuclear radiation, for example, throws the particle from the source of radiation like cannonballs from a cannon. Every particle in the medium conveying the sound is set in motion in a certain order, and the particles can exist in different phases of the sound wave. The maximum distance a particle can depart from equilibrium is called the amplitude. The amplitude for different sound waves in air varies from millionths of a millimeter up to approximately two millimeters. Wavelengths refer, in transversal waves, to the distance between two consecutive crests or troughts. The corresponding unit for longitudinal waves is the distance between a maximum compression and the next one, or the corresponding distance between a maximum depression to another. Wavelengths can vary from fractions of a millimeter to kilometers or more.

The foreground structure of the same text passage is represented in Figure 12:7 below.

[3] Gerhardsson, G. *Buller*, pp. 11–14. Bonniers 1973.

Figure 12:7. The foreground structure of a text passage represented as a graph.

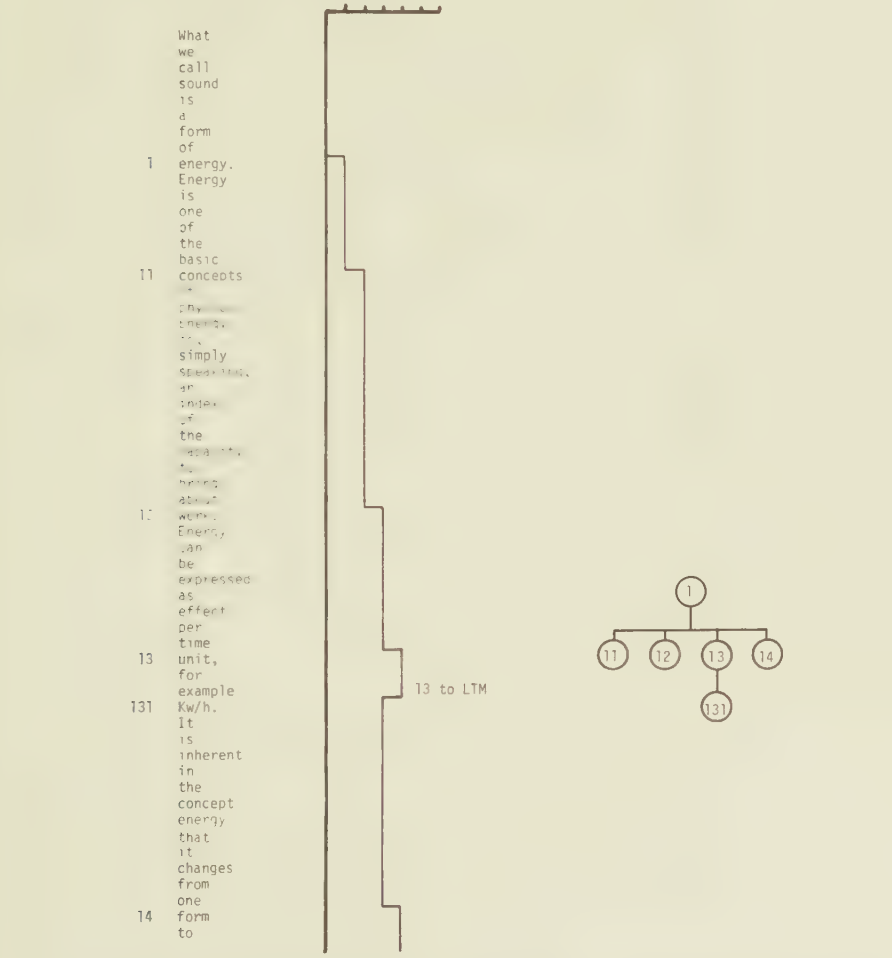



(114112 11)
in a certain pattern
(144112 12)
around a stationary point
(114112 111)
every particles set in motion in a certain order.
(114112 112)
the particles can exist in different phases at the sound wave
(114112 121)
similar to when the wind makes a cornfield ripple
(144112 1121)
the max phase is called the amplitude
(144112 11211)
waves from millionths of a mm to about two mm in air
(144112 11212)
the distance between (max phases is called wavelength
(144112 112121)
varies from mm to kilometer
(144112 112122)
is the difference between two crests for transversal waves
(144112 112123)
is the distance between two maximum compressions for longitudinal waves

The reader's aim is to transform the text shown on page 124 to a knowledge structure resembling the one depicted in Figure 12:7. According to Kintsch (1977), short term storage capacity plays a crucial role in this transformation process. An estimate of the variations in STM load during reading appears in Figure 12:8 below.

If the reading process ended with storage of simple propositions, STM would soon be overloaded and content would decay. The propositions are, however, further processed. Subordinate propositions act as repetitions of superordinate ones. In the processing example below the probability that this repetition will be effective is estimated to .90. This effect is assumed to spread upwards in the hierarchy, so that a proposition four levels above the one entering STM from the

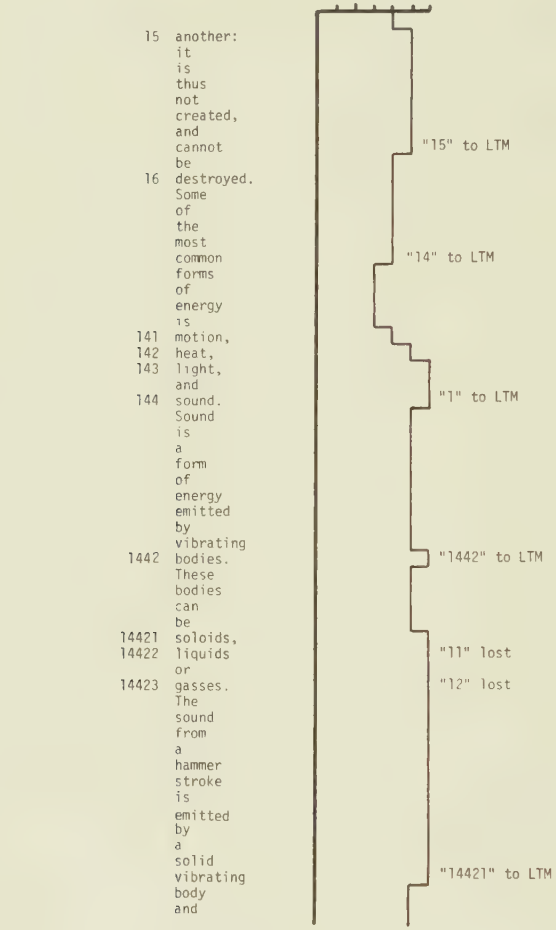
Figure 12:8. An estimate of the variations in short term memory load during reading of an unedited text. The build-up of the text base at selected points is shown in the right column. The propositional notation is the same as the one used in figure 12:7.



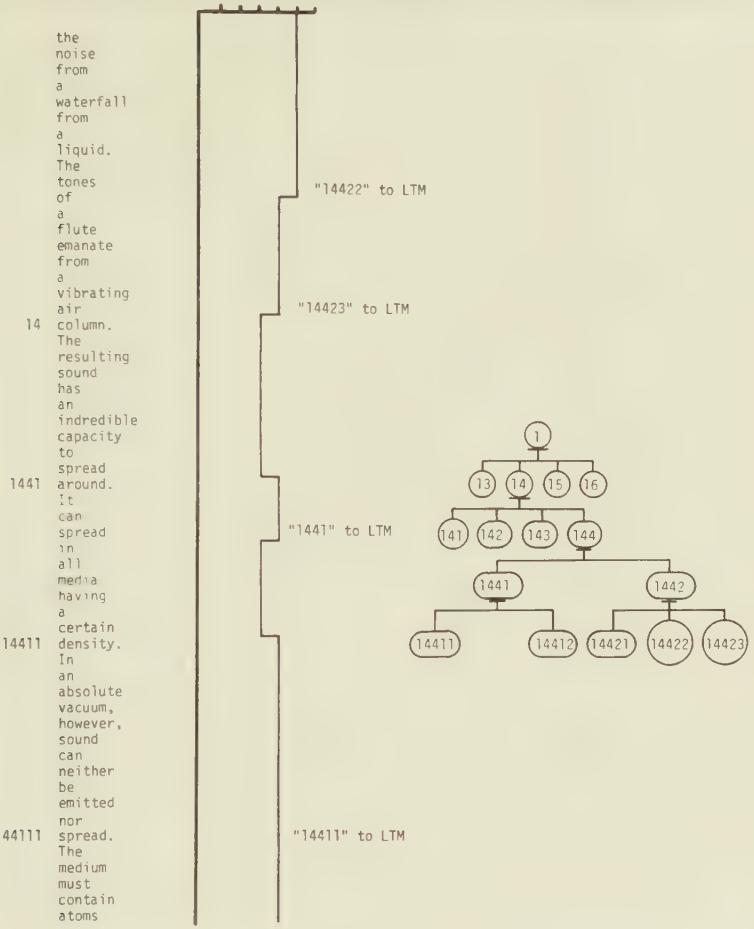
[4] Propositions at a very detailed level are not counted. Prop 2, for example consists of 3 subordinate propositions, actually.

[5] The reader is supposed to have an STM capacity of 6 chunks. It is furthermore assumed that syntactic information always is deleted if there is a choice between deleting either syntactic or propositional information. The model also assumes that STM works according to the first in - first out principle. If a proposition is repeated or foregrounded it is transferred to "LTM" (which means that it does not occupy STM capacity). It might very well be lost immediately when reading is finished, so the notation "LTM" does not imply retention over longer intervals.

Proposition fed into STM	Text	Information load and propositions lost from STM	Foreground structure at selected points

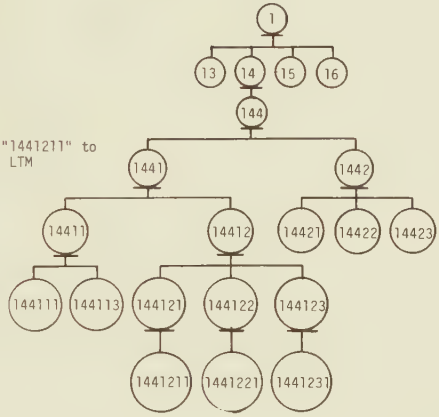


Proposition fed into STM	Text	Information load and propositions lost from STM	Foregroud structure at selected points

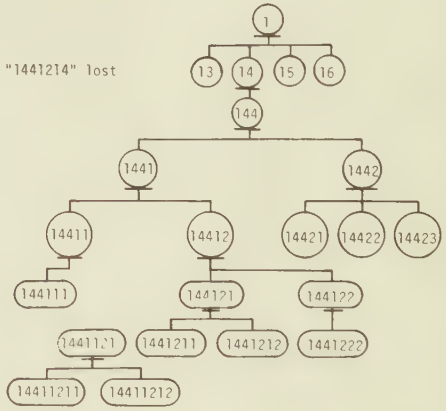


Proposition fed into STM	Text	Information load and propositions lost from STM	Foregroud structure at selected points
	and		
	molecules		
144112	and		
	have		
	a		
	certain		
144113	elasticity		
	to		
	be		
	able		
	to		
	transmit		
	sound.		
	Sound		
	spreads		
	in		
	the		
	form		
	of		
	sound		
14412	waves.	"141" lost	
	There		
	are		
	two		
	main		
	forms	"14412" to LTM	
	of		
	sound		
	waves:		
144121	transversal		
	and		
144122	longitudinal	"142" lost	
	There		
	are		
	in		
	certain		
	cases		
	more		
	complicated		
144123	waveforms,	"144112" lost	
	but		
	they		
	go		
	beyond		
	the		
	scope		
	of		
	this		
	elementary		
1441231	treatise.	"143" lost	
	Concerning	"144121" to LTM	
	transversal		
	waves		
	the		
	particles		

Proposition fed into STM	Text	Information load and propositions lost from STM	Foreground structure at selected points
	are moving up and down in the medium conveying the		
1441211	sound, that is perpendicular to the direction the waves spread in.	"1441211" to LTM	
	Concerning longitudinal waves the particles move in pulses in the same direction the waves		
1441221	radiate. Sound energy can spread in all media when it appears as longitudinal		
1441223	waves. Sound can spread in solid		
1441213	materials and in	"144113" lost	



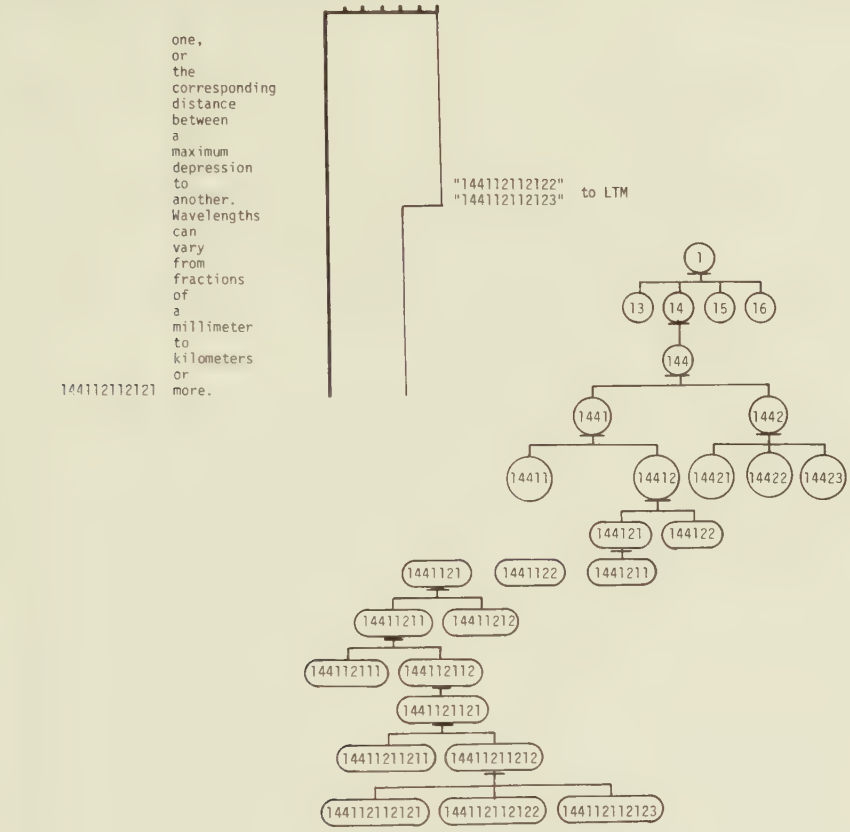
Proposition fed into STM	Text	Information load and propositions lost from STM	Foreground structure at selected points
1441214	liquids	"144123" lost	
	both		
	as		
	longitudinal		
	and		
	transversal		
1441212	waves.	"1441231" lost	
	The		
	two		
	wave		
	forms		
	appear		
	together		
	at		
1441222	times.	"1441221" lost	
	When		
	sound		
	spreads		
	in		
	air,		
	the		
1441121	molecules	"1441223" lost	
	in		
	the		
	air		
	oscillate		
	in		
	a		
	certain		
14411211	pattern,	"1441213" lost	
	but		
	around		
	a		
	stationary		
14411212	point,	"1441214" lost	
	similar		
	to		
	when		
	the		
	wind		
	makes		
	a		
	cornfield		
	ripple		
	despite		
	that		
	the		
	single		
	cornstalks	"1441121"	
	remain	"14411211"	
	in	"14411212"	
	their	to LTM	
	position.		
	Sound		
	radiation		
	differs		



Proposition fed into STM	Text	Information load and propositions lost from STM	Foreground structure at selected points
	from		
	particle		
1441122	radiation		
	in		
	this		
	respect;		
	nuclear		
14411221	radiation,		"1441122" to LTM
	for		
	example,		
	throws		
	the		
	particle		
	from		
	the		
	source		
	of		
	radiation		
	like		
	cannonballs		
	from		
	a		
14411222	cannon.		
	Every		
	particle		
	in		
	the		
	medium		
	conveying		
	the		
	sound		
	are		
	set		
	in		
	motion		
	in		
	a		
	certain		
144112111	order,		
	and		
	the		
	particles		
	can		
	exist		
	in		
	different		
	phases		
	of		
	the		
	sound		
144112112	wave.		
	The		
	maximum		
	distance		
	a		
	particle		

Proposition fed into STM	Text	Information load and propositions lost from STM	Foreground structure at selected points
	can		
	depart		
	from		
	equilibrium		
	is		
	called		
	the		
1441121121	amplitude.		"1441212" lost
	The		
	amplitude		
	for		
	different		
	sound		
	waves		
	in		
	air		
	vary		"1441121121" to LTM
	from		
	millionths		
	of		
	a millimeter		
	up		
	to		
	approximately		
	two		
14411211211	millimeters.		
	Wavelength		
	refer,		
	in		
	transversal		
	waves,		
	to		
	distance		
	between		
	two		
	consecutive		
	crests		
	or		
144112112122	troughts.		"1441222" lost
	The		
	corresponding		
	unit		
	for		
	longitudinal		
	waves		
	is		
	the		"14411211212" to LTM
	distance		
	between		
	a		
	maximum		
144112112123	compression		
	and		
	the		
	next		

Proposition fed into STM	Text	Information load and propositions lost from STM	Final foregroud structure



text will be evoked with the probability .90[4]. The empirical 'activation coefficient' probably varies considerably between readers.

This 'repetition' exploration of the fact that STM can handle increasing amounts of information during reading implies that "unrepeated" propositions decay. Kintsch & Vipond (1977) and Manelis & Yekovich (1976) have shown that this actually happens.

In spite of the "adaptive behaviour" of STM, essential propositions are lost now and then during reading. They are not available at the moment when they should act as foreground for new propositions.

When such "gaps" in the foreground structure are detected, the reader has to look back in the text for the missing propositions. This search process is guided partly by the readers internal conception of the structure organising the propositions, partly by the structure given to the text by typographical cues in the layout of the text. The text from Figure 12:8 above is for example, designed in the way shown on pages 137–139[6].

There are 2 headings in the text which demarcate 2 propositional substructures (141121 with subordinate propositions, and 14412 with subordinate propositions). Both these substructures are introduced in the same introductory passage of the text. The structure starting with proposition 14411 introduces the passage on "Wavelength and amplitude", while the proposition 14412 introduces the passage on "Soundwaves". The 3 introductory passages correspond to 3 propositional substructures; (1), (1441) and (1442). These passages could also have been labeled by headings. As they are not very long (5 to 8 lines), they do not overload STM. It is thus not probable that the reader will loose any essential propositions at this stage. Headings would not, therefore, fill a function in the reading process. The iconic/symbolic figure (Picture 2:1) repeats propositions (144121, 1441213) and (144122, 1441223). A reason for this could be that the subordinate propositions 1441213 and 1441223 are the endpoint of their respective substructure. According to Kintsch (1977) they will easily be lost if they aren't repeated. As they are not repeated in any subordinate propositions in the text, the necessary repetition has to be brought about by design features like this picture. Picture 2:2 contains a lot of information. The analogue figure in the upper part of the figure repeats the substructure 144222112 and connects it to propositions 1441211 and 1441221. The two latter propositions explain the nature of longitudinal and transversal waves. The figure declares that the relation between amplitude and wavelength is valid for both these types of waves. This fact is not contained in the text. The figure adds new information in this respect. The table in the bottom of Picture 2:2 connects the passage on "Amplitude and wavelength" to a succeeding passage on "frequency". The table thus connects different substructures to each other.

[6] From: Gerhardsson, G. *Buller*, pp 11–14. Bonniers 1973.

2 Ljud

Det vi kallar ljud är en form av energi. Energi är ett av fysikens grundläggande begrepp. Energi kan enklast sägas vara ett mått på förmågan att åstadkomma arbete. Energi kan uttryckas som effekt per tidsenhet, t.ex. som kilowatt-timmar. Det tillhör energins väsen att den kan uppträda i olika skepnader och övergå från en form till en annan: den nyskapas alltså inte och förstörs inte heller. Några av våra vanligaste former av energi är rörelse, värme, ljus och ljud.

Ljud är en form av energi som vibrerande kroppar kan avge. Dessa kan vara fasta, flytande eller gasformiga. Ljudet från hammarslag kommer från en fast vibrerande kropp och dånet från ett vattenfall från en vätska. Tonerna från en flöjt uppstår i en vibrerande pelare av luft.

Det uppkomna ljudet har en otrolig förmåga att sprida sig. Ljudet kan sprida sig i alla medier som har en viss täthet. I absolut vakuum kan ljud däremot varken uppstå eller fortplantas. För att ljud skall kunna transporteras måste mediet innehålla atomer och molekyler och ha en viss elasticitet. Ljud utbreder sig i form av ljudvågor.

Ljudvågor

Det är vanligen två olika typer av vågrörelser som är aktuella när det gäller ljud: transversella och longitudinella. I vissa fall förekommer mera komplicerade vågtyper men de faller utanför denna mera elementärt hållna och översiktliga framställning.

När det gäller transversella vågor rör sig partiklarna upp och ner i det medium som fortplantar ljudet, dvs. vinkelrätt mot fortplantningsriktningen. När det gäller longitudinella vågor förflyttar sig partiklarna i en fram- och återgående rörelse i fortplantningsriktningen (bild 2:1).

Ljudenergi kan fortplantas genom alla medier som longitudinella vågor. Ljud kan utbredas i fasta material och vätskor både i form av longitudinella och transversella vågor. Inte sällan uppträder de båda vågformerna samtidigt.

Typ	Utseende	Utbredes i
Longitudinalvåg		Alla medier
Transversalvåg		Fasta material
		Vätskor och fasta material
		Fasta material

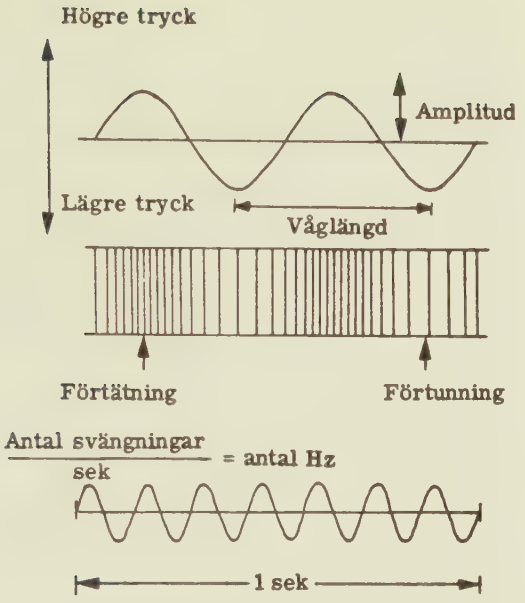
Bild 2:1

Amplitud och våglängd

När ljud sprider sig i luften svänger luftens molekyler i ett bestämt mönster men kring ett viloläge, ungefär som när vinden får ett sädesfält att bölja utan att stråna förflyttas. Därför skiljer sig ljudet från partikelstrålning, t.ex. radioaktiv strålning, där partiklar slungas ut från strålkällan som kulor ur en kanon.

Varje partikel i det medium som fortplantar ljudet sätts i rörelse i en bestämd ordningsföljd och partiklarna kan befinna sig i olika faser av ljudvågen. Det maximala avstånd en partikel kan förflytta sig på från viloläget räknat kallar man för amplitud (bild 2:2). I luft rör sig amplituden för olika ljudvågor om miljondels millimeter upp till ett par millimeter.

Med våglängd menar man, när det gäller transversalvågor, avståndet mellan två intilliggande vågtoppar eller vågdalar. För longitudinella vågor är det avståndet från en maximal förtätning till nästa maximala förtätning eller motsvarande avstånd från en största förtunning till en annan. Våglängderna kan variera från millimeter eller mindre till kilometer eller mera.



Frekvens, Hz	Våglängd, meter
1	340
125	2,7
500	0,7
2 000	0,2
4 000	0,09
8 000	0,04

Bild 2:2 Exempel på frekvenser och våglängder i luft

Picture 2:2 ties different parts of the text tighter together. Picture 2:1 repeats propositional substructures. The headings delineate propositional substructures. The design features are thus used to indicate the *structure* of the text as an aid in the reading process.

12.4 Consequences for talking book design

The main conclusion of Section 12.3 is that the readers working memory capacity is heavily strained if it is not supported by text design. Text design provide "spatial" cues for the transformation of the connected discourse to a knowledge structure, and act as cues in retrieval of information from the text (for example

when the reader has to regress in the text). The specific physical organisation of a certain text is chosen deliberately by the author. Text book illustration for example, can be used to provide a stable foreground during reading. An incorrect foreground might endanger the acquisition of the text. The author dares not take for granted that the reader provides the correct foreground himself. The author, therefore, anticipates the mental load exerted by the text (or rather by the text composition), and inserts a figure as memory support.

Text book editing releases the reader from some of the mental load exerted by the continous storage and processing of information which goes on during reading. The editor has already made some of the preparatory processing required to comprehend the text before reading starts.

It follows from the model of reading put forward in Chapter 12 that the mental load exerted during reading differs between inkprint and talking book recording. Different physical organisations of a text forces the reader to apply different reading strategies. If he does not do this, the contents of the text will get (at least partly) lost. The design which was carefully chosen to support acquisition of the text does not work anymore when it is transferred to another reading medium. It is completely futile for example trying to transfer "foreground illustrations" by means of verbal descriptions. They will not provide the intended foreground in the new reading medium. Rather they will exert extra load on human memory capacity.

This applies also to other reading media than the talking book. Blind OPTACON-readers[7], CCTV-readers[8], etc, meet with the same kind of problem. The process of information acquisition during reading is not supported by design information any more.

Design information makes it possible for the reader to read at several levels of depth in the text alternately. If he wants to acquire a general overview of the text he should read headings, summaries and perhaps some of the graphical material. If he wants to repeat a part of a book he may use his own underlinings together with graphs and summaries. If he wants to refer back to an earlier point in the text to check some piece of information, he may use headings, graphs and tables, and reference words in the margin.

Design information duplicates the connected discourse in the sense that it does not add any new information to the text. It is thus not necessary for the reader to read these parts of the text to understand the discourse. But, if he just wants the structural organisation of the text it is much easier to get it through the general design information than by reading the text all over again. The talking book reader on the other hand, lacking design information, has to stick to the discourse

[7] OPTACON is an acronym for "OPtical-to-TActile-CONverter. OPTACON is a reading machine which makes it possible for the visually handicapped to read inkprint.

[8] CCTV is an abbreviation for "Closed Circuit TeleVision". CCTV is an electronic enlarging system which can be used by visually handicapped with minimal visual acuity.

even if he just wants to repeat what he has already read. At best, he can double the play back speed of the tape recorder[9], thus reaching normal reading speed for a skilled ink print reader (about 300 wpm). The organisation of the recorded text, however, does not allow him to read at alternate levels in the manner an inkprint reader can.

This perspective on the function of design information places graphic information together with headings, summaries, typographical features in the text etc. We might use *directive information* (see Myrberg 1972) as a common label for all instances of this kind of information. Directive information makes it possible for the reader to utilise his own mental resources at an optimum. It works as an extension of STM during the reading process. The effect of this "memory support function" of directive information can be described in the following way:

> The exact wording of a phrase has to be kept in sensory storage until it can be checked against a 'syntactical hypothesis' which can transform the words to the propositional meaning of the phrase. The actual wording does not make any difference in the interpretation of the text if this check confirms the hypothesis. If the hypothesis is not confirmed, or if a sentence takes too long time to read (as in the case with recursive sentences which Coleman, 1962, have demonstrated), the reader has to regress in the text to reinforce sensory storage again. If, however, the hypothesis is confirmed, STM takes over the burden and holds the *propositional information* until its place in the text structure is determined. Then the single propositions can be disposed from STM without consequences for the readers comprehension of the discourse. If the propositions have to be kept as foreground for other propositions they are likely to be transferred to LTM[10]. Retrieval times from LTM during reading are very short. It is important that information from LTM is available in very short time during reading. Foregrounding often relies on LTM. If, for example, a subdivision of some concept is made in the text (as 'medium is subdivided into 'solid materials', 'fluids' and 'gases' in the example on page 124) more than a minute might pass from the reading of the first instance of the subdivision to the last. STM can probably not hold the superordinate concept longer than a minute. If the concept is not made available from LTM, the coherence of the text will be lost to the reader. It is not a rare state of affairs that the superordinate concept (or any foregrounded element) *is* lost when it is needed. In these instances the foregrounded elements have to be retrieved from the text instead of from STM or LTM. It is, however, equally important that retrieval time is kept at a minimum also in this case. Directive information fills the function of shortening retrieval times from the text significantly.

Talking book readers lack the supportive function of directive information. A table like "Picture 2:1" in the sample of text on page 138 above cannot shorten retrieval time from the text if it is just verbally described in a talking book. Searching for certain pieces of information in the text is very slow, as reading speed is determined by the play back speed of the recorder. Instead of effective reading

[9] With the help of "varispeech" equipment (see Trowald, 1973).

[10] "LTM" in this context does only denote that the proposition can be recalled from memory with very short access time during reading. When reading is completed the item isn't necessarily retained any longer.

speads of perhaps 4–5000 wpm during a "search regression" made by a sighted reader, the visually handicapped talking book reader is limited to the regular 150 wpm of the recording. Regressions in the text are not guided by distinctive design features in the text. Rather, they resemble a trial and error search back and forth on the tape.

The retrieval and abstracting functions of directive information cannot be reinstated in an ordinary talking book. The sequential character of the tape, together with the trial and error character of the rewind/regression functions, prevents this. It is however not necessary to preserve this unfavourable character of talking book recordings. The retrieval and abstracting functions existing in an inkprint book could be brought about by technical changes in the reading medium itself–the tape and the tape recorder. There are a few alternative measures which can improve the "readability" of talking books by making it possible to use directive information. Five alternative technical possibilities to insert directive information in talking books will be reviewed below. The alternatives "A" through "E" describe a development in sophistication.

A) A system of index signals

Index signals, that is, signals which are audible when the tape is played at high speed but not when it is played at normal play back speed, is an already existing way of reducing retrieval times from a tape recording. It is regularly used in the production of talking books in Sweden. One type of signal is given when a new page starts, another type when a chapter heading appears in the text, still another type when a subheading appears.

The system makes it possible to recognise the over all structure of the text without going down to the connected discourse. It is thus a parallel to very rapid skimming of the text which is often performed by the sighted reader. It is thus possible for the talking book reader to get a kind of abstract of the text without reading through it.

It would be possible to expand this system to include signals also where figure descriptions appear in the text. It is, however, not recommendable to use a wide variety of signals at the same time, as this requires the reader to learn a complicated code system to be able to search the text.

B) Indexing of automatic stops on the tape

There exist dictating equipment which can code automatic stops on a tape. In principle, the systems offer no advantages to the reader the first time he reads the talking book. A combination of a code of audible signals together with automatic stop indexes might however prove favorable. The main advantage with the automatic stop indexes is that the reader can insert them himself wherever he wants on the tape. They can act, therefore, as the underlinings made by sighted readers of inkprint books.

C) Discs instead of tape

The principal disadvantage of solutions "A" and "B" is that the reader still has to follow the discourse in the same order as it was first recorded. If he wants to get from page 95 to page 35, for example, he has to go through all the intervening pages. If the tape is replaced with discs instead this disadvantage disappears. There are a couple of dictating machines working in this manner. One system has "floppy discs" containing about one page of text on each, as the information medium. The discs can be selected and inserted in the recorder manually or automatically. The play-back head can be steered manually to any point on the disc immediately. Index signals can be inserted on the disc to mark, for example, headings or graphs in the text.

D) Microprocessor controlled retrieval

The indexing systems offered by the above solutions cannot in any respect compete with the "indexing" offered by directive information in printed texts. The reader of inkprint can immediately determine if a certain figure or chapter is interesting to him. He just has to read the heading (or the figure text). A talking book reader cannot, even if he uses an indexing system, tell exactly what the text following a certain index signal says until he has stopped the tape and begun reading the text.

There are however possibilities to replace the index systems with a system similar to the "free text search" utilised in computer on line systems for information retrieval. The German BRAILLEX cassette recorder provides this facility (see Review of the European Blind 1977, p 6). The microprocessor system works in the following way: A cassette recorder unit is attached to a braille key board. When the cassette is recorded, headings, figure texts etc are inserted in braille via the key board on the place in the text where they appear. When the reader wants to listen to the cassette he starts with asking the recorder for all "directive information" which has been inserted on the cassette. These words are displayed in braille, item by item. The reader can stop wherever he wants in this presentation and ask for the text connected with a certain heading to be played back to him. He can thus acquire an abstract of the book in the same way as a sighted reader with an inkprint text. He can change to a deeper level of information exactly when he wants, going from "abstract" to "discourse information" or vice versa.

E) On line reading of synthetic speech from disc memories

The microprocessor still has one disadvantage compared to inkprint. The reader is restricted in his search by the "indexes" coded as directive information. He cannot for example ask for a concept which he might have missed in the discourse earlier. For example, if he suddenly hears the narrator saying "Secondly, vertebrates have the common characteristics. . .", and the reader is unable to remember any "first",

he cannot just ask the microprocessor recorder for the label "first"[11]. An inkprint reader would just skim through the text backwards until he found the "first". If the author is clever, he has marked the "first", "second" etc with special type font, or inserted a table with the information summarised in it. It is thus not necessary for the reader to stick to the "discourse level" to find the missing item.

It is however possible to simulate even this reading behaviour with the aid of a computer system utilising an information retrieval system. The system should work with the text stored on discs in order to minimise search times. It should present the information in the form of synthetic speec[12], and it should be able to search in the text with "free text words" (that is any word appearing in the text). The reader would have a normal typewriter keyborad in front of him, and gets the text presented as synthetic speech over the telephone net.

If the text has been fed into the system from compositors' tapes[13] direct from the publisher, then special symbols indicating how the text should be typeset in inkprint, which are on the original tape, can be utilized by the talking book reader. He can key in one of these special symbols if he wants to find the next new paragraph, a change of type font, a table or a figure. He utilises the same directive information as the sighted reader utilises, even if he has never seen the lay out of an inkprint text.

These five solutions to the problem of representing directive information in talking books constitute a continuum of decreasing retrieval times from the text, and hence decreasing load on STM during reading. They do, however, also represent a continuum of increasing costs and increasing work in preparing and editing the text. The editors function becomes more and more important the more advanced the system becomes.

At the present time, the best balance between costs and reading ease seems to be the microprocessor alternative. In this case, the main work required from the editors is to select the most efficient "labels" to use as directive information. The editor has to decide if it is sufficient with the "table of contents" as search labels, or if there are some other general search concepts in the text which might be utilised. He has to discuss these matters with the reader who has ordered the book, to be able to choose the most important labels. This work will require more editing time than is allotted ot each talking book today, but it will also make the talking book far more readable than it is today.

[11] This is possible with some existing microprocessor systems also, but these are far more sophisticated than the ones referred to.

[12] *Synthetic speech* is the term for artificial vocal output from a computer or microprocessor system.

[13] *Compositors' tapes* are magnetic tapes (or paper tapes) carrying the text in digital form. Compositors' tapes are normally used as the input medium to type setting machines.

13. Cognitive ergonomics—an applied science of information based on cognitive psychology

13.1 A changed perspective on the problem of figure descriptions in talking books

When the studies of editing problems in talking books started some years ago, the explicit aim was to find a good strategy for figure descriptions. The initial formulation of the problem was stated as follows:

> "Figure description in talking books: How is graphical material from text books apprehended and retained when it is verbally described in a talking book. A talking book reader must have figures and diagrams explained aurally. How should this be done as effectively as possible? It is more difficult to remember a figure which you have never experienced visually?"

Have the research efforts initiated by this problem lead to any practical answers? The question can be answered both with "yes" and "no". "No" is the answer if "recommendations to the talking book narrators" is the requested practical result. Research has not provided talking book narrators with a simple and effective description strategy for one simple reason: there is none! What theory has contributed is the conclusion that it is impossible to give talking book readers the same conception of a verbally described figure as the inkprint reader gets from the printed original.

The visually handicapped talking book reader's difficulties to benefit from graphical information is rather due to differences between the talking book and the inkprint book as *media*, than depending on the narrator's description strategy. The exclusively sequential organisation of text in a talking book means considerable disadvantages for the reader who is trying to acquire the contents of the text. Instead of studying methods of figure description, we have to study alternative organisations of the text and alternative cues for retrieval of the contents from the text. Instead of studying the narrator's description problems, the possibilities for the editor to utilise alternative media and text organisations ought to be studied.

This is in itself a very practical answer, but there are still more practical answers to be obtained from theory. The conclusion that verbal descriptions of figures cannot produce good comprehension of the figures does not help the talking book reader. Conception II and III identified the problem of figure descriptions as a problem of editing, rather than recording, of talking books. The end point of these conceptualisation of the problem is described in Chapter 12. The answers provided in Chapter 12 have far more practical consequences for talking book

production than could be imagined when the first problem concerning figure descriptions was stated. The practical consequences of the theoretical framework provided by Conception III do, however, reach far beyound talking book recording. In the *first* place it is equally applicable to all cases of reading; i.e. other reading media beside talking books, and other reading materials beside text books. *Second*, the insight that editing effects the mental load exerted by a text implies that all human information processing can be affected by systematic information design. It opens up the possibilities to establish an applied science of information based on cognitive psychology. I have labelled this potential field of research *Cognitive Ergonomics*.

Ergonomics implies the adjustment of environmental conditions to the characteristics and capabilities of man. *Cognitive* implies that the human beings characteristics and capabilities as a processor of information is the aim for the environmental adjustment.

Every job task a human being performs can be described as transformations of different kinds. The human being converts something from an original form to a new form. These transformations can be categorised according to the initial and final state of the material processed. An example might clarify this: a person is monitoring a chemical process which must proceed at a steady temperature, or at a certain pressure. Sensors constantly give indications of the state of the process with respect to these variables on a display. If the indicators show that the permitted range of values is exceeded, he has to take necessary steps. He might, for example, manipulate the pressure regulator, or increase the amount of cooling water. In this example data concerning the state of the chemical process is transformed to energy which changes the state of the process. Input to the job task is *data*, and output is *energy*. The worker is thus transforming data to energy. (This task could of course be totally automated without affecting the principal description of the task.)

Job tasks can generally be divided into three different types of transformations:

1: Transformation of energy to other forms of energy (manual labour).

2: Transformation of data to energy (vigilance tasks).

3: Transformations of data to other forms of data (clerical work for example).

There are systematic techniques developed to study the first and the second of the above mentioned job tasks. Anthropometic ergonomics is the label for environmental design regarding the motoric capabilities of the human being. Information ergonomics is the corresponding label for environmental design regarding the perceptual capabilities of man. There are, however, no theoretically based ergonomic techniques developed to design environments to fit the information processing capacilities of man. Cognitive ergonomics is, therefore, an attempt to create a corresponding field of application for the third type of transformation mentioned above.

The aim of ergonomic science is, broadly speaking, to design environments to fit the capabilities of man. An anthropometic analysis of a job task should give

tools and conditions matching the physiological characteristics of man. An analysis based on information ergonomics should give displays and regulators matching the perceptual and psychomotor capacities of man. The cognitive capacities of man have not been subject to these types of analyses earlier. Is it that this field is considered too complex for applied science, or is it perhaps that human cognitive capacity is not considered limited in the same sense as motoric and perceptual capacity? Both perspectives are equally wrong. Cognitive psychology has during the last two decades accumulated considerable knowledge in the field of human information processing. Psychological research has during this period shown a steady increase in research on memory and cognition. Human information processing in realistic settings, with realistic tasks and materials, has replaced human behaviour in artificial settings as the focus of interest. Research on verbal learning works with connected discourse as experimental material, i.e. semantic factors rather than syntactic are stressed. Content analyses of texts are tied to the human cognitive representations of the same text. (Cf Newell & Simon 1972, Fredriksen 1972, Miller & Johnson-Laird 1976.)

Research on acquisition of connected discourse has shown a lot of limitations in the human capacity to receive and process information. The human information processing system has definite limitations regarding reception, retrieval, editing and processing of information, which are not sufficiently accounted for in the design of information material.

The partly parallel development in behavioural sciences, linguistics and computer science opens up possibilities to systematically adjust the environment to human cognitive capacity. A cognitive ergonomics is added to anthropometric ergonomics and information ergonomics.

Cognitive ergonomics is mainly an experimental technique. A theoretical description of information processing in terms equally applicable to human and automatic processing is the starting point of the analysis. Information must be registered, stored, retrieved, transformed, distributed and displayed. These types of information handling can be found in many tasks performed by human beings learning passages from text books, acquiring information from a text, performing administrative functions in office work, managing complicated devices or systems like traffic surveillance systems or nuclear plants, tracing systematic trends in data from scientific experimentation etc. Applications for an ergonomics of cognition can clearly be found in many fields.

13.2 Some fundamental concepts for ergonomic analysis of information handling

The basic concept for an ergonomics of cognition is the Information Processing System, or IPS as Newell & Simon (1972) label it. An IPS can be either human or automated. The system requires data and processing capacity to be able to work. The work it performs can be described as transformations of data (see page

146). The accessibility of these data are one of the primary concerns for Cognitive Ergonomics. Cognitive Ergonomics aims at providing the IPS with as short access times as possible to the data needed to perform certain tasks. The allocation of information processing to human or automated processing systems is another major concern. All kinds of information processing are initiated by a human operator, and also ended by a human operator. The processing required between the starting point and the end point can be allocated either to man or automata, or shared between different human beings. The processing can also be split up into several processes which can be made far in advance of the complete processing. Editing of text is one example of such preprocessing of information. These preparatory editing produces results which are stored externally until they are needed.

Cognitive Ergonomics does not aim at devising automated intelligent information processing. This field is left for those interested in Artificial Intelligence. One of the assumptions underlying Cognitive Ergonomics is that automated information processing can never provide a general purpose simulation of mental information processing. Even if the ambition would be theoretically feasible, the practical and economical obstacles would be unsurmountable. As we have pointed out above, information processing is always initiated and ended by a human being. Automated processes merely act as a support and extention of human mental capabilities (cf Wiener, 1950). It is thus unwise to try to let automata simulate human mental processing. A more fruitful approach is to try to find the "weak points" in human processing of information, and provide external support at these points. STM-capacity, and retrieval times from LTM are such weak points. This does not mean that artificial intelligence lacks relevance for cognitive ergonomics. This is far from the case. As the situation is today, however, applications of artificial intelligence utilise theories of mental processes as far as it is possible. Applications of theories on memory are, however, very rare. Cognitive Ergonomics is an attempt to show the wide applicability of such theories.

It is thus clear from the outset that only a few types of mental transformations of information will be dealt with. The main ones are *editing* and *retrieving* of data (information). Editing and retrieval both operate between a state where information is *stored*, and a state where it is *displayed*. Storage can take place *externally* or *internally*. *External* storage denotes that information is stored as data on some kind of physical medium. Text is for example stored in books, which thus constitutes an external store. Facts contained in a text can, however, also be preserved in human LTM, which is the same as internal storage. Information is retrieved from storage to *display*, which is the state where knowledge can be operated upon (cf "Knowledge State" which is used by Newell & Simon, 1972. There are also parallels to Chafes term "foregrounding".) Display can be either internal or external. Internal display is the same as STM, while external display can be a page in a book, a TV screen etc. The characteristic which defines a display as opposed to storage is that the human operator has immediate, random access to

	EXTERNAL	INTERNAL
DISPLAY	Exposed textpage, handwritten notes, TV-screen	All internal representation which gives immediate access to all items in the representation; STM-representation for example
STORAGE	Books, magnetic tapes, microfilm, registers, databases	Semantic networks in human memory

Figure 13:1. States of information in the human information handling process.

all items on display, whereas all storage is associated with retrieval times of different lengths. The relations between display and storage is illustrated in Figure 13:1.

Figure 13:1 stresses the ergonomic aspect of information systems design. The same information can be stored in "external" or "internal" storage. External display can act as an extension of internal display. Automatic retrieval systems can arrange a number of display configurations in the same manner as human information retrieval can. Editing programs, which determine what information is going to be retrieved, and how it is going to be displayed, can be prepared in advance and stored as routines in automata, or they can be stored in long term memory, and called upon when they are needed. They can also be performed by specialists who preprocess data to minimise the load on the person who is going to carry out the further processing. Text book editing is an example of this.

13.3 Aims of Cognitive Ergonomic analysis

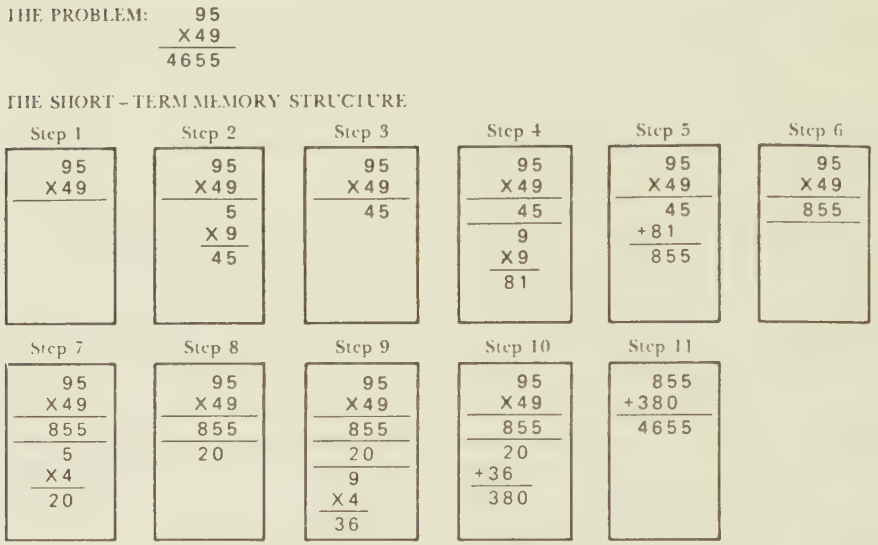
The main ambition of ergonomic measures is either to make work tasks easier for the human operator, or to make systems performance more reliable. In the first case steps are taken to lessen load on STM during the performance of a task. In the second case editing programs are developed into routines.

If the aim is to relieve human STM from some of the load a task exerts on it, external displays and stores with short access time have to take over some of the load. Human STM is utilised mainly to store retrieval rules. This solution, however, requires that the retrieval rules are matched by proper editing of the external storage and display. Editing determines which items are going to get the shortest access times. It should be noted that it is necessary to know the task

which is going to be performed with the information before any editing program can be devised. In the example in Chapter 12 the knowledge structure the reader wants to acquire has to be determined before editing can start.

An example of the use of external memories is given by experiments on "mental arithmetic". Lindsay & Norman (1972) describe the human information processing during such an experiment in the following manner:

> "The step-by-step memory requirements is shown in Figure 14—13. The memory load increases to six items at steps 4,7, and 10 and to seven items at step 9. Moreover, although not shown in the diagram, in addition to these six or seven digits, some other information is also involved—for example, the part of the problem being worked on at the moment and the amount that the partial answers must be shifted and added to each other to get to the final answer. Thus, the seven items shown in step 9 underestimate the memory load.



> Indeed, most people discover that the mental multiplication of a Twodigit number by a Twodigit numer is just at or beyound their capabilities. The limit is clearly one of short-term memory, not mental capability. Given pencil and paper, the problem becomes trivial, for now the paper substitutes for short term memory."
>
> (Page 522—523)

An example of the importance of editing to shorten access times from External memories is the design of a telephone directory. A normal inkprint telephone directory is strictly alphabetically organised. First you have the different areas consecutively in alphabetical order. Within each area, you have the second names of the subscriber in alphabetical order. If there are several people with the same second name in the directory they are arranged in alphabetical order according to their first name. Handwritten, private directories are arranged in the same way.

One of the visually handicapped clients in my current project on job design had his private directory recorded on a small cassette recorder. This is very handy when you register a telephone number. You just repeat a number you have got through the directory enquiries into the microphone of your cassette recorder, and it's there—but unedited! The numbers appear in the order you have got them, not in alphabetical order. This makes it far more complicated to *retrieve* a certain telephone number. The average retrieval time from a completed cassette is half of the total recording time, which is about 8 minutes for a minicassette. My client wanted to give me a telephone number which he had recorded in this way, and, met with a retrieval time of 10 minutes. That is quite unacceptable to a sighted user. To make the directory work, it has to be edited into alphabetical order in some way. Even such editing is not sufficient at times. A subscriber may appear under a different name than the expected one. Then references to the correct place may have to be inserted where it is likely that someone will look for the name of the subscriber.

A common example of the importance of editing text to shorten retrieval times is the experience of meeting the word "Second,..." in a text. We cannot remember having seen "First,..." earlier in the text. After a minute or so of searching, the "First,..." is finally found. Proper editing of the text in this respect might cut down search time to a few seconds. Typographical cueing (italics, indentations, etc.) might be used to reduce search time.

The above mentioned instances of editing have one common characteristic: the work to retrieve a piece of information has been split up in two steps. *First*, the information is organised according to how the information is to be used. The *next step* is the actual search for information. The first and the second step does not even have to be performed by the same person. If the principles for editing are known by both the editor and the user of the information, the two steps can very well be executed by different persons.

If the aim of the ergonomic analysis of information handling is to make a system more reliable, the work is concentrated on the editing program. Normally, LTM stores the "executive program" determining which pieces of information that should be retrieved. In situations where the operator is improperly trained, where different editing programs follow each other in close sequence or where work is performed under stress or other extreme conditions, the "executive program" might fail. In such situations, external executive control might prove safer. Research on automatic traffic control, and air safety research have often had this emphasis. In these situations it is often suitable to devise an executive algorithm which incorporates the different alternative actions. The algorithm can be performed by a human being, aided by a check list or a question-answer program stored in a computer. The algorithm can, however, also be performed by a computer, fed with data from a human operator.

Where reading is the task to be performed, computers are obviously at a loss. Algorithms can instead take the form of check lists or reading instructions in the

text. Lewis & Cook (1969) made an experiment where a legal text was redesigned to become a flow chart, incorporating a "binary checklist". The reader just had to answer "yes" or "no" at each node in the chart. The chart, and the legal text it replaced, are shown in Figure 13:2 below.

Another type of algoritm to improve system reliability is the so called "headup display" used by pilots during bad weather conditions. A lot of numerical data concerning the position of the aircraft relative to the ground are transformed to one analogue display. The display thus presents a preprocessed combination of data to the pilot (see Figure 13:3).

If the asset consists of stocks or shares which have values quoted on a stock exchange (see also paragraph G below), or unit trust units whose values are regularly quoted, the amount of tax chargeable or allowable depends upon the relative sizes of the cost price *of the asset, its* market value *on* 6 *April* 1965, *and the selling* price *of the asset.*

If the selling price is greater than the market value, and the market value is greater than the cost price, tax is charged on the selling price less the market value (less allowable expenses). If the selling price is greater than the market value, and the market value is less *than the cost price, two possibilities arise. Either the selling price is greater than the cost price, in which case tax is charged on the selling price less the cost price (less expenses). Or the selling price is less than the cost price, in which case no tax is either charged or allowed.*

If the selling price is less than the market value, and the market value is less than the cost price, tax is allowed on the market value less the selling price (plus allowable expenses). If the selling price is less than the market value, and the market value is greater *than the cost price, two possibilities arise. Either the selling price is less than the cost price, in which case tax is allowed on the cost price less the selling price (plus expenses). Or the selling price is greater than the cost price, in which case no tax is either allowed or charged.*

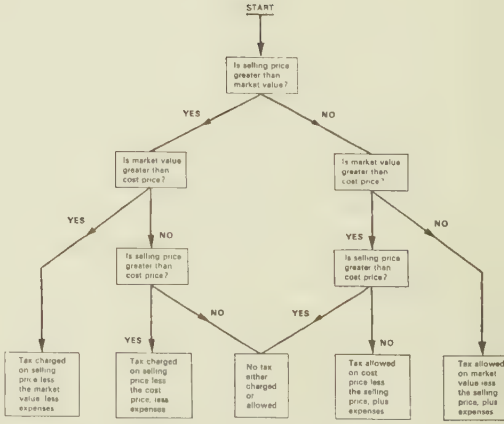
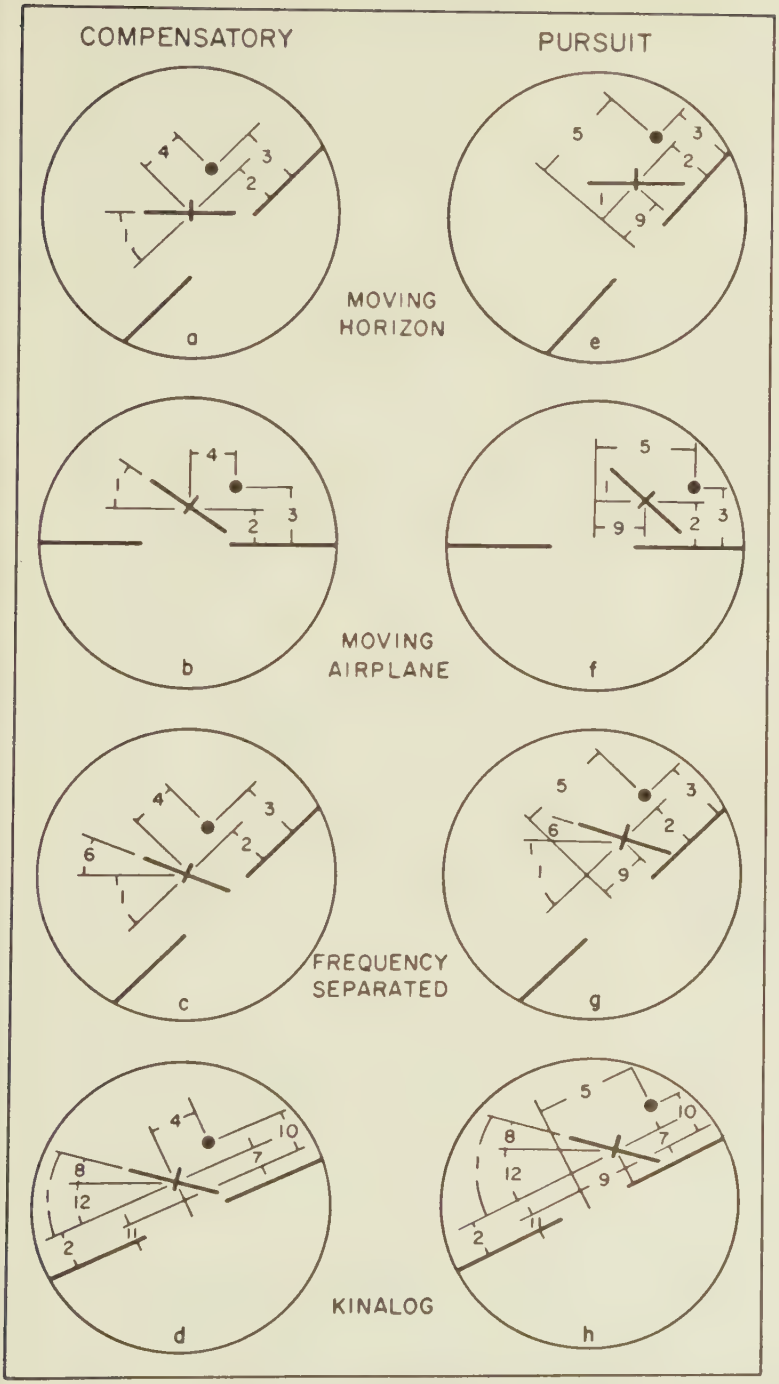

START
Is selling price greater than market value?
YES
NO
Is market value greater than cost price?
Is market value greater than cost price?
YES
NO
YES
NO
Is selling price greater than cost price?
Is selling price greater than cost price?
NO
YES
YES
NO
Tax charged on selling price less the market value less expenses
Tax charged on selling price less the cost price less expenses
No tax either charged or allowed
Tax allowed on cost price less the selling price, plus expenses
Tax allowed on market value less the selling price, plus expenses

Figure 13:2. Redesign of a legal text into a flow chart (From Lewis, 1969).



Legend:

1. Bank angle
2. Pitch angle
3 Command pitch
4. Command heading error minus sine bank angle
5. Command heading error
6. Aileron position
7. Pitch angle minus lagged pitch angle
8. Bank angle minus lagged bank angle
9. Sine bank angle
10. Command pitch angle minus lagged pitch angle
11. Lagged pitch angle
12. Lagged bank angle

Figure 13:3. A display combining several indications concerning an aircraft's position relative to the ground into one analogue display.

14. Four areas of application for cognitive ergonomics

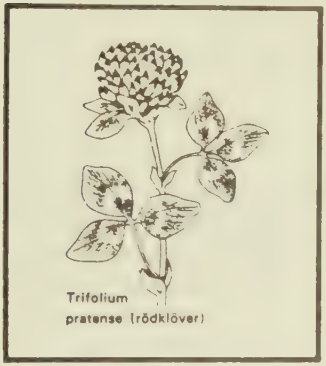
14.1 The ergonomics of text design and composition

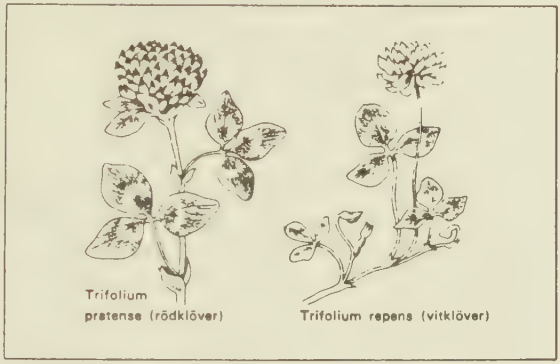
As the literature review in Chapter 11 has shown, design factors have not been of major concern for reading research. The attempts which have been made to make reading more efficient have focused on *reading techique*. Speed reading (cf Edfeldt, 1960) tried to achieve faster and more efficient reading through systematic improvement of reading behavior. Later on, the aim changed to adaptive reading (cf Lindell, 1971) instead of speed reading. Reading should be selective. Reading strategies should be chosen with the purpose of the specific reading situation in mind. Text design seems to be taken for granted, however. Those factors in text design which can serve as cues in selective reading are not studied by research on "adaptive reading". They are, however, of special concern for Cognitive Ergonomics. What "adaptive reading" requires is an alternation between different processing depths by the reader. "Reading for pleasure" of novels which perhaps first comes to mind when we think of reading is not the best example of this type of reading. Most reading is done at work or in newspapers. Reading does not in these cases proceed in a linear fashion, paying equal attention to all of the text in these instances. Rather, the reader is forced to acquire the contents (or the specific piece of information in the text he is interested in) in a limited time. The cues in the text which can provide short-cuts round irrelevant material is of utmost importance in these situations. It is very difficult to read selectively in an unbroken sequence of text. If the text is not cued properly, the reading task becomes very difficult.

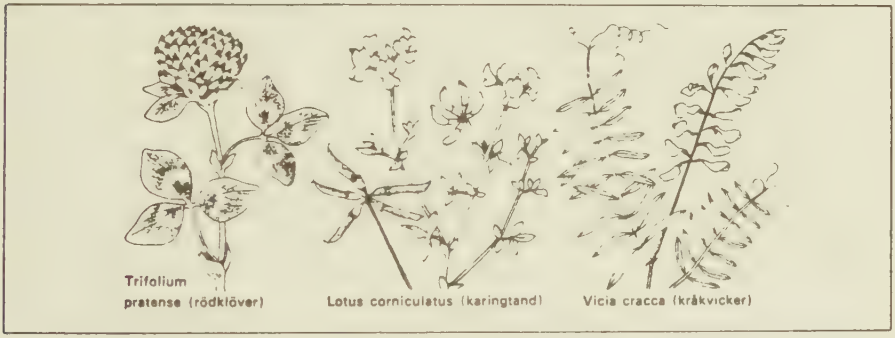
Cueing ought to reflect the propositional structure of the text. It is, however, not possible to stress all the important parts of the propositional structure in the text. An attempt to do this would just result in a confusing mess of different typefonts, special layout features, etc. Instead it is necessary to provide several parallel versions displaying different aspects of the propositional structure of the text. A brief summary can introduce or end the text. Brief summaries of background information can amplify certain parts of the text. Symbolic figures can show the relations between isolated propositions in the text. They can also provide a way of repeating ideas and categorisations of special importance. Iconic figures can act as repetitions or aid "image inducing" of important propositions. Analogue figures or tables can fill the same function when several propositions are tied together (as in a law in physics for example).

Cueing of different aspects of the text in the way described above makes it

possible for the reader to read selectively, and adapt reading to the specific purpose ha has for the moment. Functional cueing has to be based on careful analyses of characteristics of the text of the reader. Is foregrounding sufficient in the text? Is it possible for a reader with "normal" STM capacity to keep a superordinate proposition in memory until all its subordinate propositions have appeared in the text. The following example gives an instance of proper cueing to solve this problem (From: Linnman, Wennerberg, Rodhe. *Biologiboken*, p. 5. Esselte Studium 1975).







"*Red clover is a species.*
Red clover and white clover belong to the same genus.
Red clover, Babys slipper and bush vetch belong to the same family – leguminouses.

What is a species?
The word 'species' is used for both plants and animals. Man is a species, dog is a species, and chaffinch is yet another. Dandelion and cowslip are different species. If pollen from a dandelion plant attaches to the pistil of a cowslip plant nothing happens, but pollen from a cowslip plant transferred to another cowslip plant fertilises the latter one. Seeds which can grow into new cowslip plants are created in this way. A male chaffinch and a female titmouse do not mate. If this happened, however, the eggs of the titmouse would still not be fertilised. The two species are not sufficiently similar to permit any fertilisation.

The concept species thus refers to plants or animals which have a similar con-

stitution. They are also sufficiently similar to permit the offspring to breed. How different specifies originated, and what factors are responsible for heredity will be studied later on.

Genus and family
Red clover and white clover are different species, but they resemble each other very much. You can tell that they are closely related to each other. The Alpine hare and Common hare also resemble each other very much. Species which are related in this way are combined to a *genus*. Genuses then are classified into larger units called *families*. The clover species and the vetch species consequently belong to the family leguminousae. The wolf, the fox and the dog belong to the dog family, the lemming and the field vole belong to the family voles, the marten, the ermine and the badger belong to the family martens, and so on. The families are subsequently classified into still larger groups like orders and classes."

The mere physical format of the book might also be an obstacle to the reader. It is often necessary to keep a foregrounded element in memory during a text passage which covers many pages of text. If the foregrounded element is lost it might prove labourious to find the correct page despite good typographical cues. A larger page format could improve the situation somewhat, but not solve the problem. A possible solution might instead be to use a technique commonly used in alphabetical registers (telephone directories, address books, for example). The text is printed on the inner two thirds of the pages, closest to the binding of the book. The remaining part of the page is used for foreground information. The pages following a "foreground page" is cut so only the area where the text appears is left. When a new foreground appears the old one is covered by a new "foreground leaflet". The editor can also choose to cut out a piece of the new foreground leaflet, so a part of the old foreground remains. This alternative can be convenient if several foreground levels should be preserved simultaneously. The principle is illustrated in Figure 14:1 below.

Does the amount of text devoted to different parts of the propositional structure correspond to the relative importance the author attaches to these parts? Kintsch (1974) has shown that propositions which are foregrounded (or the arguments of which are repated) are likely to be retained by the reader.

Are "the right" propositions repeated? An author can quite unintentionally provide repetitions for unimportant information. It is, for example, rather common that long passages of a "footnote" character interrupt the main theme of the text. It is equally common that important classifications are not retained by the reader because they appear in the "bottom nodes" in the propositional hierarchy. A figure, or a short repetition in the margin would solve this problem. Of course it would be possible to repeat the same proposition once more in the text, but most authors hesitate to do this for stylistic reasons.

Do the requirements on previous knowledge of the concepts in the text match the readers knowledge of these matters? Is it likely that the "target group" for a certain text book has the vocabulary required to understand the text; or, put in

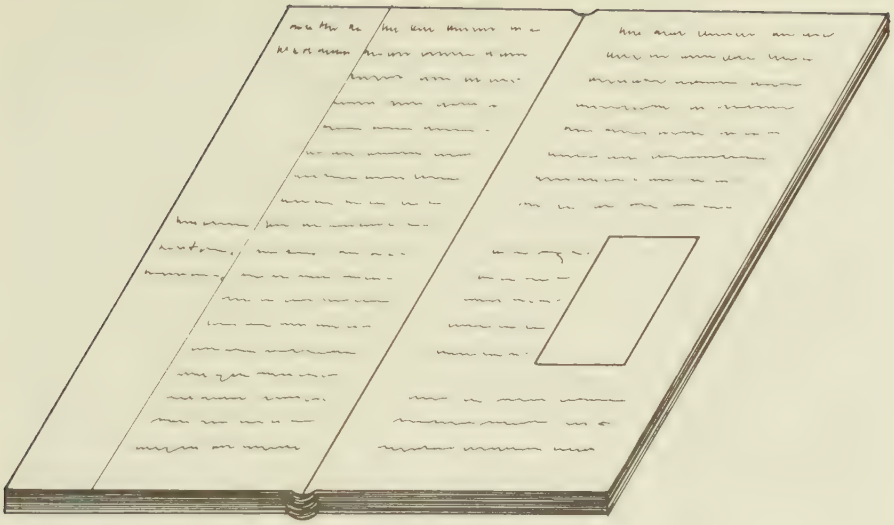


Figure 14:1. A typographical technique to make foreground information easily accessible over several pages.

Chafes terms: Can the readers provide the necessary foreground themselves?[1] Does the text overload the STM capacity of the reader? Average STM capacity of children of various ages are provided by standard norms of intelligence scales. An estimate of the readers average redading speed is also needed. These two factors can then be matched against the STM requirements of the text. If it is shown that the text overloads memory capacity, repetitions of foregrounded propositions have to be inserted. A figure might also provide the "external memory" for the foregrounded proposition. If STM problems appear due to a very long listing of categories of a concept (the concept itself constituting the foreground), typographical cues might aid the reader to make necessary regressions back to the foregrounded element.

The ergonomics of text design does not intend to provide ready digested knowledge for the reader. It could, however, be argued that the mental operations giving rise to learning are made superflous by the type of editing recommended above. Text design interfers with "mathemagenic activities" (cf page 109) in Rothkopfs (1970) terms. To a certain extent this type of criticism is justified. A perfectly edited text makes it possible for the reader to choose a level of processing himself. He does not have to read through the whole text to get a picture of its contents. He can choose to read only the interesting details appearing in supplementary notes or titles of illustrations instead of paying attention to the propositional

[1] This is not only a question of denotative meaning. It is equally important that the reader has a normal connotative structure associated with the concept. The author often requires his readers to infer different elements from the connotative structure to be able to keep the coherence of the text.

structure of the text. Text design makes it possible for the less ambitious readers to change the purpose of reading from learning the text to gathering information from it. Such mistakes can, however, be avoided if the pupils are taught to monitor their own reading, and are shown the relation between reading process and reading outcome. If the pupils read a well edited text with awareness of their own reading behaviour, text design provides *advantages* to learning. Unedited text can, for example, prohibit re-reading of a passage because it lacks indications of the text structure. The pupil who has already read the text through, and just wants a repetition will perhaps not devote the time to read it through again. It is, however, very difficult to read an unedited text in a way deviating from its "linear" lay-out.

It must be pointed out once more, though, that cognitive ergonomics does not primarily aim at producing better long term retention of a text; it points rather at measures to improve *aquisition* of the text (cf Figure 3:1, page 33). Cognitive ergonomics can, however, raise the initial amount of information gained from the text by making it easier for the reader to discover the structure which the text intends to reflect. A secondary effect of this ought to be that the material becomes more resistant to extinction. Organised knowledge lasts longer than isolated pieces of information. Cognitive ergonomics cannot, however, provide an easy alternative to the reader who lacks the basic knowledge which is essential in order to understand a text. The mental work required to understand complicated logical reasoning remains the work of the reader.

14.2 Design of feed-back and display systems

Display design was one of the first application areas for ergonomic research.

Perceptual theory and perceptual experiments were used to determine legibility of indicators of different design. The more complicated systems man was put to operate and supervise, the more difficult became the problem of legible display layouts. It was no longer sufficient to have perfect contrast conditions and a systematic layout of indicators. The problem was rather one of information overload than legibility. The ergonomic approach based on perceptual psychology could not respond to this change. Ergonomic performance measures have a very weak link to overall systems performance in these situations:

> "Typically, human factors research in the realm of information systems concerns itself with the effects of different variables operating within and/or external to the system on speed and accuracy of human information processing.
>
> For example [. . .] The results of the study then are presented to a system designer or research and development manager in the hope that these findings will be related, in some philosophical or logical way, to system performance. This integrating activity is required (although it frequently does not occur) because the measures themselves were not made in terms of impact on the system output but usually as speed and accuracy measure of the human performance alone."
>
> (Baker, 1970, p 645)

Baker's plea for theoretically based measures of performance for informations systems did not get a successful response. Some attempts to apply systems theory to the problem have been made (see Saric, 1970) but they have mainly proved the value of systems theory as an operative model. A substantial theoretical base for the ergonomic study of information systems is still lacking.

The ergonomics of cognition described in this chapter could be a fruitful theoretical base for the analysis and design of information systems. Allocation of information processing functions basic to human decisions in systems surveillance or regulation is a typical cognitive ergonomics problem. A human operator faced with a systems malfunction, or some irregularities in the environment of the system, has to collect data both from indicator panels and the system environment. Driving a car which suddently does not respond when the brakes are applied is an example of such a systems malfunction. The lack of brake response points to brake failure, but it could also depend on a very slippery road surface. The driver has to collect indices verifying one of these alternatives. His choice of action is dependent on the quality of the information he gets. The quality of the judgement of the *consequences* of different actions is also dependent on what information he can get. In a normal car, the hypothesis that the brakes really have failed could be tested by pulling the hand brakes. If it turns out that the incident was caused by a slippery road surface, this choice of action could result in a crash.

A brake failure indicator could replace the "ecological evidence" the driver must otherwise collect himself. Suppose that the lack of brake response was caused by a slippery road surface. The driver would still have several alternative actions to choose from. He could try to get off the road into a soft and snowy surrounding. His car wouldn't be damaged by this, but he would get serious trouble in getting back on the road again. He could also take a chance that the brakes will stop the car before he crashes into the car in front of him. *But* it is very difficult to determine if the slow down is proceeding sufficiently fast to avoid a crash. The speedometer gives a rough indication of the deceleration of the car's movement. Human beings are not very skilled in calculating first order derivatives, which is the processing required in this situation. It would however be possible to let an instrument take over this function instead. The instrument could for example indicate what distance the car requires to come to a stop with the present braking effect. The task left to the driver is then to estimate how long the distance to the car in front of him is. If the distance is long enough he can easily avoid the unpleasant consequences of driving off the road.

Another type of problem which could be approached with cognitive ergonomics is the effects of stress of different kinds on human information processing performance. When human operators are faced with complicated decision alternatives with several equally probable inputs, they will probably become very sensitive to stress factors of different kinds. A job design incorporating several tasks which should be performed rapidly and correctly decreases stress resistance. The human operator has to change between several "subprograms" accor-

ding to which kind of input he receives. Increased demands on the human operator, such as working speed, tiredness, loud noise etc, could make the subprogram deteriorate. The tendency for the system to break down under certain conditions could be tested with simulated tasks, requiring the same processing capacity as the real one. A description of cognitive load at different stages in processing could reveal the weak points in the job design. Automated routines could support the human operator in such cases, displaying preprocessed information for him. A parallel case to stress reactions is decreased systems performance due to understimulation. A very monotonous task, broken by infrequent, but critical decisions points, could also "overload" human capacity. Many surveillance tasks are of this character. An operator monitoring the performance of a nuclear power plant will probably not face many system failures during a year. When they come, however, it is extremely important that he observes them, and responds with the correct action. The human mind is however apt to leave infrequent events out of cognitive schemas. A simulation of system performance in critical situations could reveal weak points in the schema. Such weak points could be counteracted by including simulated indications from the system. The operator does not know when a display indication is real or simulated: he must respond in the same way in both cases. If the indication is simulated, the system itself neglects the actions taken by the operator.

14.3 Cognitive Ergonomics in job design for the visually handicapped

Many work tasks can be described as information handling tasks. Administrative jobs, for example, are essentially a sequence of storage, editing and processing of information. Large files of information are used for storage of working material. The files are cued in different ways to decrease retrieval times for the clerk who operates on it. Transient filing systems are used while the material is re-edited to a form most suitable for processing. Often the re-editing simply consists of selecting data from forms in a register, and accumulating the wanted pieces of information to a new form. This form is the actual input to information processing.

Information handling in work tasks was until about 1960 almost exclusively a function for human operators. Retrieval was a manual task. The next few years marked the introduction of automated information processing in many tasks which were earlier performed manually. Many manual routines which aim at preparing information for processing could now be automated. The systems were however rather inflexible. They could only be used when large amounts of data were treated according to a single routine.

About ten years later microprocessors began to be employed in tasks where the requirements were less well defined. These systems can be adapted to smaller amounts of input data, and less routine work. This does not mean that they are

more "intelligent" than large centralised computers; on the contrary they are a little more singleminded. The main advantage with decentralised processing facilities is, however, that they can interact with a human operator, be available at any time, and be monitored and guided by a human being while data is being processed. Information processing can be shared between automata and human beings in such a way that the capabilities of both can be utilised in the most efficient way. Automata are very skilled in storing and retrieving data; human beings are very skilled in directing the information handling processing according to changing conditions and requirements. Text processing equipment can store and retrieve typewritten material rapidly, desk top computers can store registers, tables, statistics etc., retrieve specified information and re-edit and process it. A human operator can, at any time, interrupt and redirect the work of the automata.

The close cooperation between human and automatic information processing makes job design a genuine cognitive ergonomics problem. Cognitive ergonomics can provide guidelines for the allocation of functions to men and automata, guidelines in the construction of office machines of different kinds, and also in the sharing of work tasks between different employees. The ergonomic nature of job design is especially apparent when the human operator does not possess normal information handling capacity. A visually handicapped person requires a longer time to locate and retrieve information for example. A mentally retarded person cannot perform as complicated processing as is often required. A deaf person cannot utilise the telephone. Cognitive ergonomics can provide tools to point out alternative, but functionally equivalent job designs. Tasks can be divided between different employees in a different way, or managed with information processing aids of different kinds. Registers may be equipped with more suitable index systems, or automated. Retrieval and editing of information can be automated to a certain extent. A simple example can demonstrate this:

> A tax clerk has as one of his tasks the calculation and addition of tax reductions due to investments made by different companies. This work is done with a desk top calculator, a taxation table, a form and pencil. The first operation to be performed is to notate the investment sums and the gross profit for each company on the form. A net profit is computed from these two figures, and notated in a third column. The figures for net an gross profit are looked up in the taxation table, and the tax for each of them is notated in a fourth and fifth column. The tax for net profit is deducted from the tax for gross profit. This series of operations is iterated as long as there are companies left. The sums are cumulated to a single final sum.
>
> A blind employee cannot do this work in the same way. Even if he is a rather skilled OPTACON reader acess times for single figures from the tables are probably tenfold the accesstimes for a sighted operator. A visual access time of ten seconds thus corresponds to a OPTACON accesstime of almost two minutes. Filling in the form is no severe problem if the person masters braille. If he doesn't, on the other hand, the task is almost impossible. When re editing of the data into the form is ready, the calculations can be performed at an acceptable speed if the operator masters an abacus.
>
> Many visually handicapped people cannot read at all with an OPTACON, they are slow Braille readers, and they do not know how to operate an abacus. It is

tempting to say that the task is impossible without these skills. If a cognitive ergonomics analysis is applied, some alternative solutions might however show up. We presume that the person in question is neither an OPTACON reader, nor a braille reader. Consequently he has to work with recorded input material. A personal assistant can record the balance from the companies for him. It is judged that it will take to long a time to select the wanted pieces of information from a tape recording. In this case, it is possible to get the figures from a filing clerk over the phone with recorder or dictating equipment attached to the phone. If this type of information is required regularly it is even possible to utilise automatic recording equipment which can record the information even if the visually handicapped person is not present to answer or call up. He can instead collect the information whenever he pleases. The problem with retrieval of investment sums and gross profit can be solved in this way. Next comes the problem of calculating net profit, reading out the tax figures for net and gross profit and notating these figures. A programmable pocket calculator with synthetic speech output can be used for this purpose. The rates from the taxation table are stored as a fixed program in the calculator. If the figure for net- or gross profit are fed in and the "tax rate" button is pressed, the calculator answers with the corresponding tax. The calculator is then instructed to deduct the figure for net profit from the figure for gross profit and store the result in a memory. The end result for each new company is accumulated in this memory, which thus finally contains the grand total. Upon pressing the button for recall of this memory, this final result is spoken out in synthetic speech.

In this way, much of the retrieval, editing and transient storage of information required from a sighted operator in this case are transferred to other people and to the calculator. The work can be performed by a visually handicapped person without special requirements on reading capacity.

At the present time (1977) a development project on applications of congitive ergonomics to job design problems for the visually handicapped is being carried out at the Department of Educational Research at Uppsala university. The project aims at studying job design problems and suggesting needed improvements for seven visually handicapped clients which are working in different professions.

14.4 Cognitive ergonomics as an aid in the design of information systems for the visually handicapped

The problem of gaining access to printed material is the common factor for the research problems of figure descriptions in talking books, of reading media for the visually handicapped, and of problems at work which were described in Section 14.3 above. Parallel to the project on job design for the visually handicapped mentioned above, there is another project running. This latter project, "Information provision for the visually handicapped", aims at mapping and counteracting the basic problem with access to printed matter for the visually handicapped, regardless of the specific situation or material concerned.

The basic perspective is identical with the one described in Section 14.1. Reading is a process composed of several different stages. The first stage in reading is concerned with getting access to the wanted information. If the aim is reading for pleasure, skimming of the book shelves in a library fills this function.

In some cases, the catalogue system of the library can be utilised. The criteria for a "successful search" are very vague. An interesting title or an appealing back cover might be sufficient.

Professional reading utilises another search technique. The person working in a certain area knows which journals contain the most interesting material for him. The editors of the journals have made a crude "search" or preselection for the reader. Importance and relevance of different pieces of information are thus judged by another person than the reader himself. This is the case also if some kind of automatic retrieval system is applied. The reader is confronted with a preselection of material which he can search according to his special interests. The endproduct of the search is an interesting article, or some interesting facts contained in an article.

Much reading is done on other types of material than connected discourse. Product registers, price lists, filing systems for customers or correspondence, tabular material of different kinds etc. This type of material has to be thorougly organised to meet the demands on short access times in a work task. A person selling goods by telephone must be able to find a certain piece of information while he is speaking to his customer. To satisfy such requirements, a very detailed classification of the material has to be used. The end product of any search must be a single fact.

When the search process is completed, the process of acquiring information from the text begins. The criteria for "having acquired knowledge from the text" also differs between reading situations. When reading "for pleasure" one has to get a cohesive picture of the plot in the book to benefit from it. It is necessary to remember who is who in the book, the order in which things happen, and the general background the author is referring to in different parts of the book. The reader is however not expected to answer questions on details in the book after having read it.

A pupil reading a text book must proceed in a different manner. He must be able to recall the important aspects of the text after having read it. It is essential for him to acquire the logical structure of the text, to learn important facts by heart and follow the logical steps in the discourse. The criteria for a successful acquisition of the text are not determined by himself, but by his teacher or the text book author.

The acquisition of information from a file of customers or a product register used in an office is satisfactorily carried out when a specific fact has been transferred from the register to a form, or some other kind of work material, or to another person, asking for the information. The "reader" is not required to keep the information in memory longer than it takes him to complete the transfer.

In all these cases, visual reading is utilised both for search and acquisition. The search and acquisition processes are also very intimately related in many cases. It is difficult to say when search ends and acquisition begins in, for example, professional reading. As we pointed out above, a preparatory selection is made already by the editors of journals. This does not mean, however, that the reader

can skip the search process himself. Search for interesting information is manifested in varied reading speed, jumps in the text etc. The border between search and acquisition process is rather arbitrarily drawn. Liberal cut off criteria are often applied to ensure that the reader himself can make the final judgement concerning the importance of the material. Search can be made fairly efficient if the text is cued with directive information.

As we pointed out in Chapter 12, the problems associated with directive information are, however, often overlooked when texts are prepared for the visually handicapped. The project "Provision of Information for the visually handicapped" aims at determining the needs in this respect, and the possibilities to meet them with existing or newly developed methods.

It is only recently that methods to produce information for the visually handicapped have been devised which can meet at least some of the needs. Up till today the capacity of talking book producers and braille producers have not been sufficient to cover even a minute part of what a sighted person has access to. Synthetic speech or automatically produced braille from compositors' tapes (see footnotes on p ●●●) do, however, seem to be within reach in the near future. These techniques are very powerful compared to their "manual" predecessors. The OPTACON has given many visually handicapped persons personal access to printed matter without any intervening conversion method. The regional libraries in Sweden have started a "recording service" open to all visually handicapped at work.

These methods have made it meaningful to study search problems in reading also for the visually handicapped. As supply was so minute compared to demand earlier, search for information was no practical problem. You cannot search for information you don't know anything about. If it proves possible for the visually handicapped to utilise compositiors tapes, the supply does, however, increase dramatically. How should search be performed with these techniques? A synthetic speech recording, or braille print out of whole journals or books is not very practical. It would be too expensive, and would require extremely long reading times from the visually handicapped reader who perhaps only is interested in a small part of the material. With a reading speed of 150 wpm or less (as would be the case for both braille reading and vocal recordings), it would, for example, take more than 24 hours to read a daily newspaper. This is clearly unacceptable.

The project "Provision of Information for the Visually Handicapped", sponsored by the Swedish Board of Education, aims at suggesting solutions to the abovementioned kind of problems. The general approach is the same as in the "figure description studies": What does the reading process for a sighted reader look like? What kind of directive information is utilised? How should directive information be designed to fit the visually handicapped reader and fulfill the same function? Experimental process studies of sighted readers behaviour under different design conditions are planned within the project to answer these quesitons. The requirements for a "search system" can thus be specified. Two

different types of solutions to the search problem are studied. Automated information retrieval systems working either interactively with the reader, or in batch[2] is the most advanced solution (cf page 144). A second solution to the problem of directive information is microprocessor-steered cassette recorders (cf page 143).

The basic supply of text from both these solutions is a text bank stored in machine readable form (on magnetic tape for example). Such text banks do already exist for other purposes. Agreements can be made with publishers and printing houses to deliver compositors' tapes to the text bank as soon as the inkprint version of the tape is printed. Each visually handicapped "customer" has an interest profile specifying a number of code words which cover the area he is interested in. These code words are integrated into a information retrieval system which selects the portion of the text where this code word is included. The selected material is collected on a tape which is delivered to an information service agency for the visually handicapped. The material is transferred to braille or synthetic sppech at this stage, whereafter it is delivered to the visually handicapped customer. If the service works as an interactive system, utilising a terminal, this can be connected directly to the Information Retrieval system. It might even prove possible to utilise the typesetting commands on the tape as a direct translation of the directive information in the inkprint text. The typesetting codes can perhaps also be utilised to select abstracts of articles which can be delivered to the customers in a batch system. The customer can then decide for himself if the material is sufficiently interesting to be ordered in full.

The use of compositiors' tapes, together with braille or synthetic speech output is of course not a generally applicable system. In the first place, only printed material can be produced in this way. None of the typewritten material which is flooding the desks of most clerks can be made available in an information retrieval system.[3] A large scale on line system can not be available eight hours a day five days a week. Urgent material which must be handled immediatedly has to be taken care of in other ways. Small amounts of material only required to be used once is not suited to the system. Furthermore, if the system works in batch it is an open question if it is possible to create a search and acquisition process which can replicate the characteristics of ordinary visual reading. The project "Provision of Information for the Visually Handicapped" aims at studying the requirements on "directive" functions in the system experimentally. In addition it is necessary to compare the advantages and disadvantages of different automated and traditional systems for different purposes.

[2] A system which produces printed (or recorded) output periodically.

[3] The use of text processing automata instead of ordinary typewriters might, however, open up also this possibility.

15. A theoretical outlook

In the introductory chapter the iterative character of the consecutive formulations of the problem of conception I, II and III was stressed:

> "A good formulation of the research problem leads to a theoretical reformulation of the problem as well as providing an answer to the practical problem. The new theoretical formulation of the problem at the same time implies reformulations of the practical problem and/or better ways to solve it. At the risk of getting lost in this iterative process, always spotting still greener grass on the far side of the hill, you have to stop the iteration at some point and try to make a major practical breakthrough in spite of the theoretical shortcomings that stick to the last problem formulation."
> (p. 20).

It follows from this perspective of problem formulation that Conception III has produced new theoretical problems as well as new practical applications. The applications have been dealt with in the previous chapter. The implications of the theories of text acquisition treated in Conception III remain to be explored, however. A lot of empirical research on the basic problems of text acquisition has already been carried out, but one gets the feeling that this is only the tip of an iceberg.

The development of research on text acquisition is of utmost interest for educational problems. Problems of describing the outcomes of learning, and the learner's acquisition strategy have been treated in a research program initiated by Marton (see Marton, 1975, 1976). A conference on applications of cognitive theory to educational problems held in Gothenburg 1976 among other themes featured the implications of research on text acquisition (see Waern, 1976).

Much of the research in the field of text acquisition has, however, treated problems related to reading strategies rather than problems of text desing. The main interest in the present context is the consequences for text design and composition. How could the complexity of a text be assessed? Recent research on readability, utilising the conceptual framework provided by text acquisition research, gives a new perspective on the problem of readability of text.

Kintsch (1977) questions whether it is possible to assess general readability scores without taking the readers capabilities into account (cf page 123). Backman (1976) has made a critical review of readability research from the same point of departure.

The problem of complexity of figure descriptions in talking books is of the same basic character as problems of readability. There is consequently a strong theoretical kinship between the theoretical framework of Conception I and Conception III. You could say that "The search for the unit of meaning" (cf Sec-

tion 4.5, page 40) has continued throughout the book. The question of measurement of mental complexity of information was approached in Conception I, with methods devised by Savin & Perchonock (1965), Ladefoged (1959) and Miller & McKean (1964). The fundamental theoretical problems are much older, however. Savin & Perchonock's method of measuring verbal complexity with the "overflow method" relies on Miller's (1956) article on human STM capacity. The ideas expressed in this paper has as one their starting points bishop Berkeley's problem of how many "mental units" the human mind can grasp at any one time. Ladefoged's attempt to demarcate the unit of meaning in language perception relies on Titchener's Principle of Prior Entry. Miller & McKeans method of assessing the complexity of different grammatical transformations utilises the same basic theoretical attitude as Donders (referred to in Sternberg, 1969)did in the 19th century. The main drawback of these approaches for the problem of assessing text complexity is, however, that they assume that there is an "elementary particle" of meaning. This assumption directs attention to the processing of single phrases or words. The structural characteristics of a text is overlooked. Research on text acquisition based on the text grammar approach takes such characteristics as its starting points. This turns the initial problem of complexity of figure descriptions into a problem of structural complexity of texts. Figures, and other design elements, are merely aids in the transformation of text to knowledge. A lot of new research problems are exposed by this approach.

The relation between different structural characteristics of text composition and the reader's acquisition difficulties could act as a "Conception IV". What is the relative effects on acquisition difficulties, for example, of number of structural levels in a text, and amount of information at each level? Could different text book authors' style of writing be distinguished by means of structural descriptions of their texts? How do texts in newspapers, novels, and text books differ?

Fredriksen (1975b) has shown that inferences required from the reader cannot be distinguished from statements actually appearing in a text when the reader is recalling it. How do failures to make the inferences required affect acquisition of a text? How do different features of text composition affect the reading process? Carpenter & Just (1975) have shown that regression in a text often occur at pronouns. Do other "foregrounding" features give similar effects? The effect that subordinate proposition act as repetitions of superordinate ones has been demonstrated by Kintsch & Vipond (1977). Replications of this study, and studies of the detailed characteristics of the "repetition effect" might be carried out.

A model predicting effects of design features has been described in Chapter 11 and 12. The model gives a lot of opportunities for empirical tests. The *reliability* of text descriptions made by the model ought to the determined. Kintsch (1977) reports that a manual for the transformation of connected discourse to a propositional structure is underway.[1] Such a manual probably does not apply to

[1] Kintsch (1977) also reports a method of assessing the coherence of the overall structure of a text, which might be applicable also for whole text books. No methodological details are given, however.

the present model, however. If whole text books should be described, it is too complicated to transform all of the text to propositions. The shortcut devised in Chapter 12 permits long texts to be described, but there is perhaps more intuitive judgements involved in the description than there is in Kintsch's system. If the system proposed here is not reliable enough, it has to be revised and specified. This probably results in a more laborious system. A compromise between reliability and ease of application has to be made. How much should descriptions made by different "judges" be permitted to digress? How should an "index of digression" be devised?

There is already a lot of research carried out in the field of text acquisition. A further *theoretical validation* of the model put forward here is still needed, however. The introduction of "semantic constraints" as a component of the model is one example. The possibilities to identify the semantic constraints is a question of reliability of the description. The psychological reality of semantic constraints in the transformation of text to knowledge is however a question of validation. Several empirical tests of the psychological relevance of semantic constraints could be imagined. Does the title of a text influence the reader's conception of it? Will the interpretation and retention of statements in a text be affected by its title? another important facet of the model is the assumed effect of repetitions of propositions on the transfer from STM to LTM. What are the specific effects in a "text network" of repetitions of propositions?

The model is said to be "ergonomic". This label is chosen to stress the view the author holds that storage and retrieval of information during reading can be influenced by systematic text editing. The text page acts as an "external memory" (cf Newell & Simon, 1972) for the reader. A text which strains the short term storage capacity of the reader can be made easier by a systematic use of comprehensive graphical information, stressing, repeating and relating important points. Such measures do not, however, affect difficulties brought about by difficult words, or concepts unknown to the reader. A study of these two different sources of difficulty in acquisition of text would show how useful an ergonomics of text design and composition is. Kintsch & Vipond (1977) report an analysis of the causes of aquisition difficulties for two speeches made by American presidential candidates, where a conventional method of assessing readability proves inferior to an analysis of propositional structure, when it comes to explaining comprehension difficulties. There are probably many more cases where difficult words and long sentences are used in a text with very simple macrostructure. In the same way there are probably texts where the reverse conditions prevail. What are the empirical effects on acquisition difficulties in these two cases? What is the effect of improved text editing for texts which differ in these respects? How do readers with different reading strategy, aim and knowledge of the subject react to them?

Another interesting ergonomic problem is the effect of different access times to different items in the text. The use of typographical features to stress certain concepts or parts of a text is, ergonomically speaking, a way of shortening access

times for the reader wanting to refer back to these parts of the text. A systematic text design can thus make retrieval times sufficiently short to make it unnecessary to burden STM with this information. How do readers utilise such features of a text? What access times are acceptable to different readers in different contexts? Can these be used to distinguish different readers?

The main problem treated in this book is the unfavourable effects a tape recording has on text acquisition compared to printed text books. As we have already pointed out in Chapter 11, this is the basic problem of reseearch on audiovisual media also. The questions put by AV media research have been rather straightforward:

> "How do different media affect the learner? Is it favourable to present a single message in several media at the same time? Is colour TV superior to black and white TV for educational purposes?"

No conclusive answers have been reached, however. From the perspective of cognitive ergonomics this is not very surprising. AV research never took the learner's task, nor the knowledge structure of the text, into account. The effect of colour and black and white TV is probably the same if it is calculated for a number of unspecified learning tasks. If, however, a task which requires a lot of conceptual discriminations is presented to the learner, he might benefit from the colour TV presentation. The superiority of colour TV will only appear if colour is utilised as a cue to the knowledge structure. Colour might, for example, be used to mark all instances of a certain conceptual category as opposed to the instances of another. In tasks which have a simpler conceptual structure, this function might very well be performed by another cue; arrows, for example. It is also possible to structure a task in other ways than by colour cueing. An alternative way would be to build up a picture on the TV screen gradually, as overlay pictures are used with overhead projectors. There is thus no consistent repeatable effect of using colour TV in education. Colour can be replaced by other, functionally equivalent features. The same answer applies to the question concerning the value of multimedia presentations. If the messages in the media only duplicate each other there will be no effect of presentation mode. If one of the displays is used as a support for the message presented in the other one, an effect will occur. One of the displays could act as foreground support for the other. If the task to be performed is so easy that it does not require any memory support, there will of course be no effect. If two different messages are presented in different channels the effect will of course be negative.

There is a number of new research questions which can be posed (and some old questions which could be reconsidered) within the framework of Cognitive Ergonomics and theories on text acquisition. In many instances psychological and educational research has not described human performance in terms of planning, selecting a strategy of action, setting criteria of, and monitoring performance etc.

Subjects in experiments have not been looked upon as active and adaptive.

Instead of trying to reveal how a human operator succeeds in producing the same overt output in spite of drastically changing inputs, the aim has been to relate input to output in a mathematical function. Cognitive psychology and Cognitive Ergonomics focuses on the *process* linking input to output instead. The present treatise in no way covers the prospects of such a "process" approach. It merely serves as an outlook.

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